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JOURNAL OF ECONOMIC ENTOMOLOGY
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The Importance of the Microenvironment in Insect Ecology[1]

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In recent years the importance of the physical environment has been ignored in many investigations of insect biology and ecology. There have been exceptions to this generalization—as, for example, the work of Wellington and his colleagues in Canada (Wellington & Henson 1947, Wellington 1948, 1949a, 1949b, 1950, Wellington *et al.* 1950)—but, in general, there has been a preoccupation with the biology and physiology of the insects and the biotic factors of the environment. There are, no doubt, good reasons for this development; but better balance will result through a more thorough consideration of the physical factors of the environment, particularly those of microhabitats.

Most ecologists believe in the concept of the ecosystem, that is, living organisms and their non-living environment are inseparably interrelated and interact upon each other (Solomon 1949). No one factor or group of factors can be singled out as having the most significance. Consequently, it is not proposed that undue emphasis be given to physical factors. However, if we are to understand fully the behavior, distribution and abundance of insects, the environment must be evaluated and analyzed at the place where the insect meets it. By this is meant analysis and evaluation of the microenvironments.

WHAT IS A MICROENVIRONMENT?—It is the immediate environment in which the organism actually exists. This microenvironment consists of various biotic and abiotic factors just as do larger environments. The prefix "micro" is used because we are dealing with small organisms, and their environment is frequently quite different from the one which we experience as humans.

Because of the confusion over the term "microclimate," it is necessary to clarify some terminology (Schilling *et al.* 1946, Wolfe *et al.* 1949, Geiger 1950, Wellington 1950). In recent times, microclimate has been used to cover everything from the conditions at the surface of a leaf to variations between local weather stations separated by several miles. For clarification, this wide range can be divided into three categories. These categories are somewhat intergrading and are suggested for convenience of discussion.

The first is that which the meteorologist usually has in mind when he considers microclimate. He thinks of the variations of climate in a small area perhaps two or three square miles in extent (Wolfe *et al.* 1943, Brunt 1945, Sutton 1953). Such factors as topography, urban influences, proximity to water, soils, soil drainage, snow cover, vegetation and others contribute to this variation (Geiger 1950). This category may be called local climatic variations, but it has also been referred to as topoclimate, microclimate, local climate, and mesoclimate. The local climatic variations are of considerable

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importance to plant growth and undoubtedly influence insects both directly and indirectly through their effect on the plants.

In the second category are placed the variations in the layer of air near the ground, that is, the layer of air normally beneath the standard weather-instrument shelter. It is the subject of Rudolf Geiger's book entitled "The Climate Near the Ground" (Geiger 1950). We might also think of this as the "plant climate" and it corresponds roughly to the ecoclimate of Uvarov (Uvarov 1931). The actual thickness of this layer will depend on the height and density of vegetation. Vertical gradients are frequently very sharp and change rapidly (Schilling *et al.* 1946).

Entomologists and some ecologists are probably more inclined to think of a still smaller category. They think of the conditions under the bark of a tree, or in ants' nests, or in a burrow in the soil, or amidst the stamens of a flower. That is, the environments of insect microhabitats. For purposes of discussion, this may be referred to as the "insect climate."

USE OF STANDARD WEATHER DATA.—In the development of meteorology during the 18th and 19th centuries it was found necessary to standardize methods. The objective at that time was to determine and describe the environment in which man lives. To eliminate variations, the standard shelter was developed. Its height was fixed at about 4 to 6 feet to avoid the extreme variations which occur in the layer of air below this level. The data obtained from instruments in such shelters allow the climatologist to compare factors over a period of time. He can tell us how today's weather compares with that of last year and how it differs from the average obtained over a period of years. This macroclimate analyzed by the climatologist is human climate and is of little value when information is needed on the vertical and horizontal variations in local climate, the "plant climate," or the "insect climate." Data from weather shelters are data from a special microenvironment—the weather shelter. They may not even parallel the situation in other nearby microenvironments (Thornwaite & Leighly 1943).

These last statements do not mean that weather bureau records are useless to entomologists (*cf.* Wolfe 1945, Wellington *et al.* 1950). These records have allowed the climatologist to develop a pattern of the human environment over the earth, to determine climatic variations in time, and to analyze periodicity of extremes of such phenomena as rainfall, temperature and wind. These data in turn have been used by entomologists and ecologists to analyze the limits of distribution and abundance of various species. Many valuable studies of this type have been made of such insects as the pale western cutworm, alfalfa weevil, codling moth, spruce budworm, forest tent caterpillar, beet webworm, chinch bug and the wheat stem sawfly. Bioclimatic studies are continuing on a more intensive basis, as witness the studies of fruit flies in the Hawaiian Islands. In the future, such studies undoubtedly will make even greater contributions to our knowledge of insects. However, only when we are fortunate enough to have the microenvironment of the instrument shelter parallel the microenvironment of the insect, will the use of standard weather data alone lead to success in such studies. In more complex situations, it is necessary to make special and detailed observations.

FACTORS CONTRIBUTING TO VARIATION.—Within the area embraced by a macroclimate there exists an intricate and dynamic matrix of small climates. These heterogeneous groups of small climates are, of course, influenced by the macroclimate with the seasonal and diurnal changes of the macroclimate reflected in the climates of microhabitats. The amplitudes of these changes may be greater or less than those of the macroclimate.

There is not time in this brief discussion to go into detail examples and analysis of why microclimates differ from those recorded in standard weather shelters or why local climatic differences occur. (See Salisbury 1939, Brunt 1945, Wolfe 1945, Chauvin & Aguilar 1946, Schilling *et al.* 1946, Geiger 1950.) However, a few points should be mentioned. Topography is very important as it relates to insolation and air movement. As compared to a convex land form, such as a hill, a concave land form, such as a valley, will have a much lower daily minimum temperature, a larger temperature range, more frequent

frosts, and lower winds. In the layer of air near the ground, radiant heating and cooling are very critical in determining temperatures. The influence of soil type, soil cover, soil drainage, and vegetation on microclimate is closely related to their effect on heat flow. As a result, temperatures many degrees apart may exist within a few inches of each other.

Another factor—rainfall—is more variable than is generally realized (Wolfe 1945). A study in Oklahoma (Thornwaite 1937), for example, showed large differences in rainfall in a rather small area. The rainfall at Guthrie was 1.17 inches; while the rainfall 10 miles to the northeast was 1.50 to 2.00 inches or more; and in an area of about 2 miles square, 12 miles to the northeast, it was 2.5 inches. Furthermore, a large area 15 miles to the southwest had about 0.1 inch of rainfall. This concerns only amount; the distribution of rainfall in time, in addition, has great ecological significance.

The development of urban areas also modifies local climates. This would appear to be due to the extensive covered area, reduced evaporation, artificial heat, and air pollution. In general, urban areas are warmer than surrounding rural areas.

In 1931, Uvarov made the following statement in his classical review of insects and climate: "In spite of the obvious importance of the ecoclimates for the proper understanding of the actual conditions of existence, very little work has been done on the subject. . . . " By ecoclimate, he meant the local climatic variations and the plant climate. Since that time, and particularly since World War II, such data have been accumulating (Geiger 1950). On the other hand, precise information on the conditions in insect microhabitats is extremely scanty. Data obtained by Wellington (1950) have indicated the importance of such studies. He found that even under winter conditions, when the sun is at low elevations, heating is still sufficient to raise exposed coniferous foliage more than 2° C. above the surrounding air. In summer, the leaves were found to be 8° C. above the surrounding air during the day, and 3° below at night. Under snow on a branch, the diurnal temperature range was 18° C., while in the air it was 23°, and on exposed bark it was 26° (Curtis 1938). In addition, humidities in small spaces or near surfaces, which are very difficult to measure, may be radically different from the surrounding air (Yarwood & Hazen 1944).

These microenvironments should not be considered as independent of the insects, as it is well known that insects modify the conditions of their environments. Sullivan & Wellington (1953), for example, have shown that the nests constructed by tent caterpillars modify the temperature and humidity of the microenvironment and hence influence the development of the caterpillars.

PROBLEMS OF INSTRUMENTATION.—As indicated earlier, weather bureau data are not applicable for most microenvironment studies of insects and hence the entomologist must obtain his own. There are several reasons why this is not easy. The lack of adequate instrumentation is probably the biggest problem facing the individual investigator. This lack is twofold—instruments have either not been developed, or if developed are frequently so expensive as to still be out of reach of many investigators. Furthermore, instrumentation for microenvironmental research in the field has lagged far behind that available for laboratory use.

Many of the instruments and techniques which ecologists have been accustomed to using in macroenvironmental research are not adequate for an analysis of microenvironments. Radiation effects are so important that the standard mercury-in-glass thermometers are almost useless. The data obtained by the use of such thermometers are not the temperatures of the microenvironment, but the temperatures of the thermometer bulbs exposed to the particular conditions. These are not the same (Fairchild 1942). Similarly, the hair hygrometer is inadequate to determine differences in humidity gradient near the ground. Where rapid changes are encountered, some type of thermoelectric hygrometer must be used.

The problem is not hopeless. However, instruments must be selected with care and with the needs of the particular project in mind. First, it might be well to suggest a list of minimum of equipment any field entomologist will need to describe the environment in which his studies are conducted. This list is selected to give the maximum information for the

smallest cost. It would include an aspirating psychrometer, a black globe thermometer, and an anemometer. In some cases, to these should be added some type of evaporimeter (Thornwaite 1940) and a rain or snow gauge. The placement of these instruments and the frequency of observations will depend upon the particular problem, but they should be standardized and reported. It is probably a better practice to take no data than to report meaningless temperatures and humidities.

For more detailed investigations of microenvironment, the problem becomes more difficult (Baum 1948, Jehn 1948, Kelly *et al.* 1949). In many cases it will be found that instrument design must go hand in hand with research progress, as intensive microclimatic studies require special instrumentation. The minimum list necessary to define a microclimate cannot be stated explicitly, as the exact items will vary with the problem. However, mention should be made of certain instruments and problems.

The importance of the effect of radiation on thermometers used to determine ambient air temperatures is not always realized (Wellington 1949c). If the temperature of the walls, sky or other features that "see" the thermometer is higher or lower than the air temperature, the thermometer will gain or lose heat by radiation, and the indicated temperature will not be the true air temperature. Perhaps the best way to reduce this error is to use a thermocouple as small as can be conveniently handled, enclosed in a single or double cylindrical shield of polished metal (Eggert 1946, Kelly *et al.* 1949, Vaartaja 1949). Thermistors also offer some promise for the future (Platt & Wolfe 1950).

Temperatures and heat flow studies are a vital part of any microenvironmental research problem (Kelly *et al.* 1949). For estimating the rate of heat loss by convection, the dry-bulb temperature of the air and the rate of air flow must be known. The calculation of the rate of heat loss by radiation involves the temperatures of surfaces or the direct measurement of emission. Small heat flow meters are available for measuring directly the heat flow through surfaces. Radiometers are available for measuring total solar and sky radiation and the intensity of radiation from a surface. The black plate radiometer of Gier & Dunkle (1951) measures whole spectrum net radiation, including sunshine, diffuse sky radiation and atmospheric radiation. Since the plate is exposed to forced air motion, its temperature is close to air temperature, and the net radiation observed is itself very nearly what an exposed leaf surface experiences. The black globe thermometer (Bedford & Warner 1934) is a hollow, blackened copper sphere, with a thermometer or thermocouple at its center. If located in the sun, the globe temperature will reach a level somewhat above that of air temperature, determined by the balance between the net heat received by radiation and heat loss by convection. Either can be calculated if the temperature departure and the air velocity at the sphere are known. The large size is inconvenient for some applications. In other cases, blackened thermocouples or thermocouples in small black objects may be useful (Wellington 1949c).

The measurement of visible light is of special importance in certain studies. Not only should the intensity of this light be measured and compared for the various situations, but its duration, quality and relationship to total radiation should be studied (Wolfe *et al.* 1943, Shirley 1945).

As a minimum list of objective climatic factors describing the well being of plants, Brooks and Kelly of the University of California at Davis, have given the following: continuous records of air temperature at 20″, wet bulb temperature at 20″, black globe temperature at 30″, and soil temperature at −4″. These should be supplemented with records of hourly mean wind velocity, wind direction, black atmometer readings, and precipitation.

APPLICATION OF DATA.—The mere accumulation of reams of data sheets will not solve problems. The vast amount of labor required to reduce the data to useful form is staggering. For example, in the orchard heating investigations conducted recently by the University of California Agricultural Experiment Station, interpretation of all the findings recorded in 30 nights required more than a year. In another study in Texas, a year's basic data used 1700 recorder rolls, the equivalent of 33 miles of data (Jehn 1948). Microenvironment research should concentrate on the solutions of specific problems. The data collected and the

methods utilized should be designed to clearly relate to the ecology of the organisms. We should study insects and their microhabitats, and not microclimates without reference to their contained organisms.

Early workers and even some recent workers have misapplied environmental data in attempts to solve their problems. For example, data from one area or year have been used to interpret phenomena in another area or year. Data obtained from a small segment of the population have been applied to a whole population or even to the entire species. Laboratory and greenhouse studies have been directly applied to organisms living under natural conditions. Furthermore, attempts to correlate such data with activity have often been made without considering all the factors of the environment. These errors are obvious, but nevertheless continue to recur.

The problem of adequate sampling is also serious. If one wishes to compare, for example, temperature in an orchard and a nearby field, the use of a single station in each area does not provide adequate records for a reliable comparison. It is necessary to obtain sufficient data in order to estimate the variation and to make reliable comparisons. One possible solution would be to obtain continuous records from a number of instruments installed at numerous randomized points in each area. This, however, is usually prohibitive in cost, since it requires a considerable number of expenseve instruments. H. G. Wilm (1946) has suggested a modification which may be of some value in entomological problems. In his method, a relatively small number of instruments were placed in each area. These instruments were not at fixed positions for the duration of the study, but moved after each sampling period to a new random position. These moving gauges were supplemented by a few fixed gauges. In one such study, 80 rain gauges, moved after each rainfall to new sites on each of 20 plots, produced an estimate as efficient as if 400 fixed gauges had been used.

In conclusion, it can be stated positively that studies of insect microhabitats alone will not solve our problems of insect abundance—however, it is a province of the field of insect ecology that should be developed more than it is at the present time. In other words, a more thorough knowledge of the interrelationships of insects and their microenvironments is needed. This knowledge can probably be obtained through cooperative research by entomologists, ecologists and meteorologists.

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The Insect and the Plant Disease[1,2]

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The title is intended to connote a field of scientific inquiry and includes the three inseparable basic components, the insect, the disease producing entity, and the plant which is host to both. This description and analysis are primarily from the standpoint of the entomologist-ecologist but with due regard for and appreciation of the several specialized disciplines that contribute to it. The insect may be studied as a separate entity, with perhaps scant attention to its host relationships; the disease producing entity can be isolated and classified and some of the viruses can even be brought to a relatively pure state in a test tube. But when insect, host plant, and disease producing entity are brought together, then the approach is the biological-ecological one.

VARIED PROBLEMS.—The problems in this field are extremely varied but in general they fall into three categories: the plant disease caused by a microorganism which is carried to the host plant by means of insects, the toxin induced disease, and finally the disease caused by the insect transmitted virus.

In the first category can be mentioned the devastating Dutch elm disease, with its close relationship between fungus and beetle vector; a somewhat similar disease of mango in the State of Pernambuco, Brazil; the shot hole borer of tea, an almost universal pest of tea in Ceylon,

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which again is an ambrosia beetle; Stewart's disease of corn, a bacterial disease which overwinters in its beetle vector and which is of especial interest to synecologists because of the possibility of predicting outbreaks based on weather; rot of wheat following billbug feeding and the rots following attack by the corn earworm and the European corn borer.

With the exception of many plant galls, the toxin induced diseases of plants are caused by sucking insects. Attempts at classification of these diseases have been based on symptoms only and, on this basis, three general and very loosely drawn categories can be established; the localized spotting of leaves and stems, often confused with trauma or a simple withdrawal of cell contents; a condition where the toxic effect is evidently due to translocation of the toxic substance beyond the feeding point, and finally the more extreme cases where the toxic effect is on the whole plant.

In the first class, the spotting of leaves by Coccids is perhaps the most familiar. Many of these are considered to be strictly localized but there is plenty of evidence of diffusion of toxicity beyond the feeding point, resulting in zonate spots. Insect galls appear to be definitely localized with no translocated effects noted. The hopperburns are among the oldest known toxic effects of insect feeding and the nature of the injury is still a matter of controversy. Some leafhopper induced diseases fall into the second class however, where the plant is affected beyond the feeding point, and wilting and formation of adventitious buds follows. *Planococcus citri* (Risso) removed from jack fruit in Brazil and fastened singly onto the leaves of cacao plants caused no visible injury to the leaf but resulted in the abscission of the newly emerging leaves. Mealybug stripe is an example of the translocation of a toxic principle down to meristematic tissue where it affects the chloroplasts in such a manner that areas of chlorosis develop on the leaves after they have grown out and the unaffected tissue has become normal green.

The two best known examples of the third category, the systemic toxic effect, are psyllid yellows of potato and tomato and mealybug wilt of pineapple but the toxic effects of *Xerophloea vanduzeei* Law. have been recently described as systemic and froghopper blight of sugar cane should propably be considered in the same category.

The insect transmitted virus diseases constitute the third and probably the largest and most important category if, as appears likely, the insect vectors are discovered for many virus diseases that are not now known. Even without regard for the rapidly expanding knowledge of the occurrence of virus diseases, some of the most devastating diseases of agricultural crops throughout the world are in this category.

GLOBAL PROBLEM.—The problem of insects in relation to plant diseases is a global one, and with the development of agriculture along modern lines (which appears essential if the world is to be fed) is becoming more and more acute. In tropical areas, the vast forests are being revealed as reservoirs of hitherto unknown insects and diseases, only awaiting the growing of a suitable crop and the host transfer of insects to establish diseases of the crops which may be limiting. A prime example of this is to be found in the Gold Coast and all along the great forest belt that exists along the west coast of Africa, where cacao has become the mainstay of the native economy. While the industry was developing in virgin forest areas, the host transfer of insects, and with them the diseases, was quietly taking place. There is strong evidence that several species of capsid have transferred in this way to become a limiting factor in the establishment of new cacao plantings and the maintenance of old ones. Even more serious is the spread of a group of virus diseases of the cacao from forest trees by the agency of mealybugs of several species. It has been freely predicted that the growing of cacao along the whole of the west African coast is doomed to destruction unless successful control measures can be found. In Ceylon, it has recently been determined that a similar group of viruses of cacao exists, with similar mealybug vectors and in all probability with similar wild host tree relationships. In between these widely separated areas lies the island of Trinidad, with another group of mealybug transmitted viruses of cacao.

Sugar cane mosaic was first recognized in 1917 and is now known as a destructive disease in many sugar cane producing

countries. The case of tomato spotted wilt is another example of how widespread a disease can become throughout the world. First described from Australia on tomato, it is now known from all over the world. In Hawaii, it can be a destructive disease of pineapple plants and fruit. This thrips-transmitted disease is unique in its vector-virus relationships even though the thrips species involved varies with the geographical area.

Mealybug wilt of pineapple is another disease of world wide distribution limited only by the climate suitable for the host plant. In many primitive areas, with shifting cultivation, small scale pineapple growing is not materially affected but as soon as the crop becomes a commercial crop, grown on the same land cycle after cycle, then mealybug wilt becomes a limiting factor. Already, growers in the newly opened pineapple areas in South Africa are beginning to notice mealybug populations on the increase and this will be followed inevitably by increasing wilt incidence.

Wherever *Helopeltis* is found, agricultural crops suffer from their attack which is extremely toxic and damaging. Coconuts are grown over a wide area geographically but immature nutfall is a general problem. In some places this is ascribed to weather conditions or inadequate agronomy but there is definite evidence that several capsid species are contributors. Some idea of the toxicity of these insects can be gained from the statement that one or two *Amblypelta* per tree can render an area non-bearing.

The most recently recognized international virus disease is that affecting the citrus areas of the world. Known as Tristeza, the sad disease, in Brazil, it is probably destined to be a limiting factor wherever suitable root stock-scion combinations are used in citrus growing.

Curly top, classic disease of sugar beets and other crops in the western United States, has its counterpart in the Argentine, and on the basis of symptoms at least, in the beet leaf curl transmitted by *Piesma quadrata* Fieb. in Continental Europe.

The examples referred to above have dealt with those viruses and other diseases which affect widely scattered areas throughout the world. There are however many more that are restricted, at least currently, to relatively small areas. Yellow leaf of New Zealand flax (*Phormium tenax*) is a newly recognized virus disease which is believed to be endemic to New Zealand. Phloem necrosis of tea is limited to a certain altitude and rainfall zone in Ceylon and, strangely enough, a serious disease of tea induced by the toxic feeding of one species of Lygus bug occupies the same restricted area. A gnarled savoy-like curl of kapok seedlings caused by the toxic feeding of a mealybug is known only from a single kapok nursery in Ceylon with the insect responsible not yet determined as to species.

RESEARCH ASPECTS.—The research aspects involved are as varied as the problems themselves. A fungus or bacterial disease may be disseminated in a great many ways, and insects may be only one of these. All information concerning modes of dissemination would therefore be relevant. There would be little point in attempting the control of an insect vector unless its role in the spread of the disease was important enough that a substantial reduction in disease incidence could be expected if the vector were to be effectively controlled.

Of particular interest to entomologists are those diseases where a symbiotic relationship exists between the disease organism and the insect. These relationships, such as exist between the ambrosia beetles and their fungi, for example, can be found in several insect groups, widely separated taxonomically, although it is in the Diptera and Coleoptera that most of the examples are found. Research in this field offers many opportunities for the anatomists and the histologist, provided that there is good liaison between these workers, the microbiologist, and the field entomologist, for by these means the seasonal history of the association between organism and insect can be determined.

In the case of the toxin induced diseases, we are first confronted with the problems of establishing the disease as a toxic effect, and the criteria are still not well defined. The first step is the elimination of trauma as the cause but this is not always entirely possible. Many of the leaf curls probably are combination effects of both toxic injection and actual mechanical damage. Histological examinations of affected cells often eliminate mere cell sap withdrawal as a major

factor. On the nature of the toxins there is little direct evidence. Some appear to function as enzymes. There is some evidence for hormone-like action; indeed the hormones appear to be the only known class of compounds that function at similar concentrations.

The non-infectious nature of the toxins needs demonstrating but this is difficult. Some insects carry viruses through the egg; other viruses might be so short lived in susceptible host plants that an infectious nature could not be demonstrated. The more complex the toxin, the closer to a virus disease in symptomology and epidemiology the toxemia becomes. Another difficulty is the mechanism of toxic action when time and space are considered. How, for example, does a toxin act if there is a latent period for symptom development? Is this just translocation time? If not, what then? Could the toxin act on the genes in somatic cells of the plant, and if so, how could this phenomenon be separated from the vegetatively transmitted virus or the so-called non-infectious chlorosis?

Specificity is one of the most important sources of evidence for the toxic action of specific insects. But here again, these are conditioned by host reaction. *Empoasca solana* DeLong feeding produces only discrete chlorotic spots on amaranth but a typical hopperburn on cucurbits. Studies on specificity also involves the complex problem of biological strains of insects. Taking only the mealybugs as an example, there is plenty of evidence that many of the best known species are actually groups of biological strains. This may complicate a problem in several ways, and *Dysmicoccus brevipes* (Ckl) in Hawaii can be quoted as an example. The two known strains differ in their toxicity to pineapple plants and in their susceptibility to attack by encyrtid parasites. Furthermore, if a strain of mealybugs on pineapple plants is primarily a sub-surface feeder, with only occasional movement up to the leafy portion of the plant, then the factors conditioning this movement would be significant with respect to the incidence of wilt. Mealybugs apparently must feed on the paler green inner leaves of the plant before they can effectively induce wilt. Mealybug wilt in the State of São Paulo in Brazil is typically of this origin; that is, large mealybug colonies are almost universally encountered on the sub-surface portions of the plant but wilt is seen only in conjunction with evidence of leaf feeding.

The analogy between the toxic effects of insects' feeding and the action of certain plant hormones is another fruitful field for research and the possibilities of inducing somatic mutations or at least carry-over effects on vegetative progeny through toxic feeding are not too remote. The tissues on which sucking insects feed may well determine the toxic effect on the plant. This aspect is well documented in connection with numerous studies on leahoppers but actually there is much more to be done. Currently we are dependent on the presence of feeding tracks to make these determinations, but these have never been described for most sucking insects. Furthermore, there is a weakness in the assumption that a feeding tract that penetrates intra-cellularly to the phloem and xylem tissues affects only these tissues and blandly disregards the effect on the parenchyma cells penetrated en route. The inter-cellular feeders are perhaps less suspect but, again, that is another assumption.

The phototopisms of *Helopeltis* bear a significant relationship to its attack on many crops. Years ago, tea in Java was pruned in strips on the grounds that the insect would not freely cross open spaces. In Ceylon, it can be observed that cacao pods are attacked more heavily on the inside of the tree than on the outer branches and this is indeed an important factor in reducing control costs by limiting spray application to the inner branches. Why, then, are young shoots on the outer periphery of old trees, and on young seedlings growing in relatively open spaces, attacked? There is an interesting conflict here between a phototopism and a nutritional requirement that must be the subject of research if *Helopeltis* control in both phases is to be achieved.

The entomologist's field for contribution to the problem of the insect transmitted virus disease has materially clarified in recent years. When viruses were first prepared in various kinds of crystalline states, it looked for a time as if virus studies were soon to be completely dominated by the biochemical approach. As time passed, however, the inevitable

dominance of the plant virus disease as a field problem in its own ecological niche asserted itself so that now the biochemical approach is recognized for what it is—a highly significant but single facet of a many facetted problem.

To this problem the entomologist can bring a two-fold approach—the study of vector-virus-host plant relationships and quantitative population studies correlated with these relationships. These are the basic studies necessary to a proper understanding of the field problem and subsequent control measures. They are broad categories however and research opportunities within them are almost unlimited. For example, when an insect vector arrives in a field crop, the spread of the virus will depend, among other things, on the percentage of the insects carrying virus, the length of time it takes for others to acquire the virus, its latent period in the insect, if any, and the number of successive feedings during which it can transmit the virus to other plants. Obviously, control measures directed against the insect will be conditioned by these factors. A freely moving insect that can acquire and transmit in a few minutes a virus with a short incubation period in the plant will present a much more difficult control problem than one which requires a longer feeding period, has a definite latent period for the virus in its body and perhaps a longer one in the crop plant. The latter might possibly be stopped in its tracks by some of the newer residual insecticides but about the only hope for the former is a residual insecticide which will prevent the insect feeding in the first place.

Some of the factors I have mentioned are now loosely covered by the term "vector efficiency." Actually the term currently expresses the relative success obtained in laboratory and greenhouse transmission studies. There is little or nothing known, beyond speculation, as to the causes of these differences in the capacity of insects as virus vectors.

If insect population studies are quantitative and carried on with due regard to host plant sequences and the role of the host plants as virus reservoirs, they can be of great economic importance. In some cases, the vector can be attacked at its source and its breeding on the wild virus hosts prevented. This can involve large scale operations—either by direct control measures such as insecticidal sprays, or better perhaps, in the long run, by adequate range management. In the case of curly top disease, it is clear that misuse of the range lands has resulted in a distortion of the plant species complex which favors the introduced weed hosts of the insect vector.

On the purely theoretical side, the position of the insect vector in the evolutionary process whereby viruses arise and spread cannot fail to be of significance. With *Circulifera tenellus* (Baker) now recognized as a Mediterranean species it can be postulated either that some unknown endemic vector remains to be discovered in the area currently affected by curly top or that a latent virus existed in that area and became the curly top virus once it established biological liaison with the introduced insect. The latter alternative would require that the original latency, if already a virus, be seed transmitted in some hosts. This is at least one problem which has felt the impact of taxonomy, and while a more biological approach to taxonomy may be helpful in some cases our dependence on the taxonomist should not be overlooked.

INTERNATIONAL ASPECTS.—The international aspects of the problems discussed in this paper require consideration. The movement of plant material, even seeds, internationally, especially by air, imposes a severe burden on quarantine officers. With dormant stock it is impossible with any known diagnostic methods to determine the freedom of such stock from virus diseases. Growing in quarantine is possible when transfer is accomplished through official bodies but practically prohibitive in the case of private importations. The development of reliable quick diagnostic methods would be invaluable. But it is in the constructive long range viewpoint that multilateral international action can best be visualized.

The development of resistant commercial varieties is the most practical control measure known against insect transmitted diseases. Throughout the world where food crops have been grown in regions isolated until recent times, the establishment of genotypes differing in their relative resistance to disease can be expected. If these could then be brought together at a central quarantine station, preferably

on an isolated island, together with all the strains of the viruses known to affect them, the potentialities for resistance could be rapidly determined. Breeding programs could then be initiated, perhaps at an equally isolated breeding station, which should result in the development of improved and resistant commercial varieties.

A second promising method and one which circumstances may force into use is control by the use of protective inoculations with mild strains. The quarantine station would be the ideal place for such testing since mild strains from far removed places might well be more efficient than those native to a given area.

The movement of insect pests and associated diseases can be expected to increase. The problem is clearly an international one requiring multilateral action and would appear to be a suitable function for the plant protection section of United Nations Food and Agriculture Organization.

Laboratory Studies on the Toxicity of Thirteen Insecticides to the Tobacco Hornworm[1]

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Since the advent of the chlorinated hydrocarbon insecticides, the following compounds have been reported by various workers as being effective against the tobacco hornworm, *Protoparce sexta* (Johan.): toxaphene, TDE, DDT, CS-708, methoxychlor, parathion, Metacide, dieldrin, aldrin, and endrin. There has been much difference of opinion concerning these compounds—in some cases one or more workers reported that a material was very good while others obtained practically no control. CS-708, toxaphene, and TDE have undergone the most extensive field and laboratory testing, and the latter two have been used commercially for several years. The use of toxaphene was sharply curtailed when it was found that an undesirable flavor was imparted to treated tobacco of certain types. Endrin has recently been shown to have certain advantages over the insecticides presently recommended. Laboratory tests were undertaken in 1953 in order to evaluate the comparative toxicity of insecticides against the tobacco hornworm and to help explain some of the discrepancies regarding the effectiveness of certain of these materials.

REVIEW OF LITERATURE.—Markovitch & Stanley (1942) gave LD-50 values (micrograms/gram) for a group of inorganic insecticides applied as stomach poisons to tobacco hornworms. These values ranged from 15 micrograms for Paris green to 230–420 micrograms for sodium fluosilicate. Stanley (1950) reported laboratory data which suggested approximate LD-50 values (micrograms /gram as stomach poisons) for 2nd and 3rd instar larvae as follows: dieldrin, 9; lindane, 19; TDE, 41; CS-645A, 47; and DDT was relatively non-toxic at 500 micrograms. Dominick (1951) showed toxaphene, TDE, and CS-708 to be effective against tobacco hornworms under field conditions. Allen *et al.* (1953) presented data showing that endrin compared favorably with CS-708 and TDE on hornworms and had the advantage of quicker action.

METHODS.—Between June and October approximately 7,000 tobacco hornworm larvae were collected from tobacco fields which were either untreated or were known not to have been treated for at least 2 months, placed singly in ventilated 1-pint ice cream cartons, and brought into the laboratory for treatment. All larvae were treated within 24 hours, and those held overnight were fed while awaiting treatment. Most of the larvae were collected in the morning and treated in the afternoon.

The larvae were arbitrarily divided into three size groups for treatment—small,

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Table 1.—LD-50 and LD-90 values (expressed as micrograms/larva), and the ratio of the LD-50 values to those of endrin, of insecticides applied to three size groups of the tobacco hornworm.

	Topical									Stomach					
	Large			Medium			Small			Large			Small		
Material	LD-50	Ratio of LD-50 to Endrin	LD-90	LD-50	Ratio of LD-50 to Endrin	LD-90	LD-50	Ratio of LD-50 to Endrin	LD-90	LD-50	Ratio of LD-50 to Endrin	LD-90	LD-50	Ratio of LD-50 to Endrin	LD-90
Endrin	42	1.0	219	2.9	1.0	6.3	0.51	1.0	6.3	9.9	1.0	49	0.11[1]	1.0	0.85
Parathion	52	1.2	183	9.9	3.4	64	2.8	5.5	12.3	15.7[1]	1.6	54	—	—	—
Isodrin	87	2.1	400	7.6	2.6	29	3.0[1]	5.9	56	15.3	1.6	138	1.1[1]	10	3.1
Lindane	206	4.9	1,235	—	—	—	—	—	—	209[1]	21	398	—	—	—
Malathion	481	11.5	1,276	61	21	553	23.6[1]	46	92	355	36	1,621	—	—	—
Dieldrin	482	11.5	2,589	—	—	—	—	—	—	—	—	—	—	—	—
Aldrin	487	11.6	1,359	—	—	—	—	—	—	—	—	—	—	—	—
Heptachlor	1,058	25	4,005	—	—	—	—	—	—	—	—	—	—	—	—
Toxaphene	1,363	32	5,778	32	11	138	30	59	112	143	14.5	6,025	—	—	—
Q-137	1,393[1]	33	4,423	176[1]	61	1,060	92[1]	180	405	1,622[2]	164	5,371	—	—	—
CS-708	1,595	38	5,689	—	—	—	—	—	—	656[1]	66	11,800	—	—	—
TDE	2,622	63	9,813	376[1]	130	2,620	37	73	367	878	89	3,192	22.5[1]	205	58
DDT (8% at 4,000 microgr.)	>4,000	>100	—	2,334	805	9,897	366	717	1,342	4,416[1]	446	28,040	158[1]	1,436	1,125

[1] Based on three dosage levels (others, four or more).
[2] Based on two dosage levels.

medium, and large. The average weight per larva, determined for 50 larvae representative of each size group, was as follows:

Size	Weight in Grams		Instar
	Average	Range	
Small	0.9	0.6–1.1	2nd and 3rd
Medium	2.5	1.2–4.0	3rd and 4th
Large	5.4	4.1–7.5	5th

In the contact poison tests, individual larvae were treated by delivering a measured drop of insecticide in dioxane solution to the dorsum of the first thoracic segment with a 0.25-cc. tuberculin syringe, the plunger of which was actuated by a micrometer caliper (Trevan 1922). If insecticides were sufficiently soluble, 1 mm.^{3} of solvent was applied, but if large doses were required and the compounds were not sufficiently soluble, a maximum of 4 mm.^{3} was applied. All materials were essentially pure chemicals except toxaphene, heptachlor, and CS-708 which were of technical grade. After treatment the insects were returned to the cartons, supplied with untreated tobacco, and placed in a post-treatment room.

In the stomach-poison tests, a measured drop of insecticide was placed on a 1-cm.^{2}-piece of tobacco leaf, the solvent allowed to evaporate, and the treated leaf section introduced into a carton containing an untreated larva. No other food was provided for 24 to 48 hours. When the entire leaf section was consumed, usually within 24 hours, untreated tobacco was introduced. In a few cases, where the treated section was not completely consumed within 48 hours, the larvae were discarded.

In both series of tests the treated insects were examined daily for 6 days and fresh food provided to those larvae which were not moribund or dead. Control larvae were given comparable dosages of solvent or solvent-treated leaf sections. Worms which appeared to be diseased or parasitized were eliminated from the records.

From 30 to 50 larvae were used at the various concentrations for the determination of dosage-mortality data. Four or more points were determined to calculate each LD-50 value, with a few exceptions. The average percentage mortality for each concentration was converted to probit mortality (Bliss 1935), and the adjustment was made for natural mortality (Abbott 1925). The coefficient of correlation and the regression equation were derived (Hayes & Garber 1927), and the calculated LD-50 and LD-90 values were obtained for each size group. Points observed and calculated lines were within reasonable agreement in most cases.

Results and Discussion.—The LD-50 and LD-90 values, expressed as micrograms per larva, for the three size groups and the ratio of the LD-50 values com-

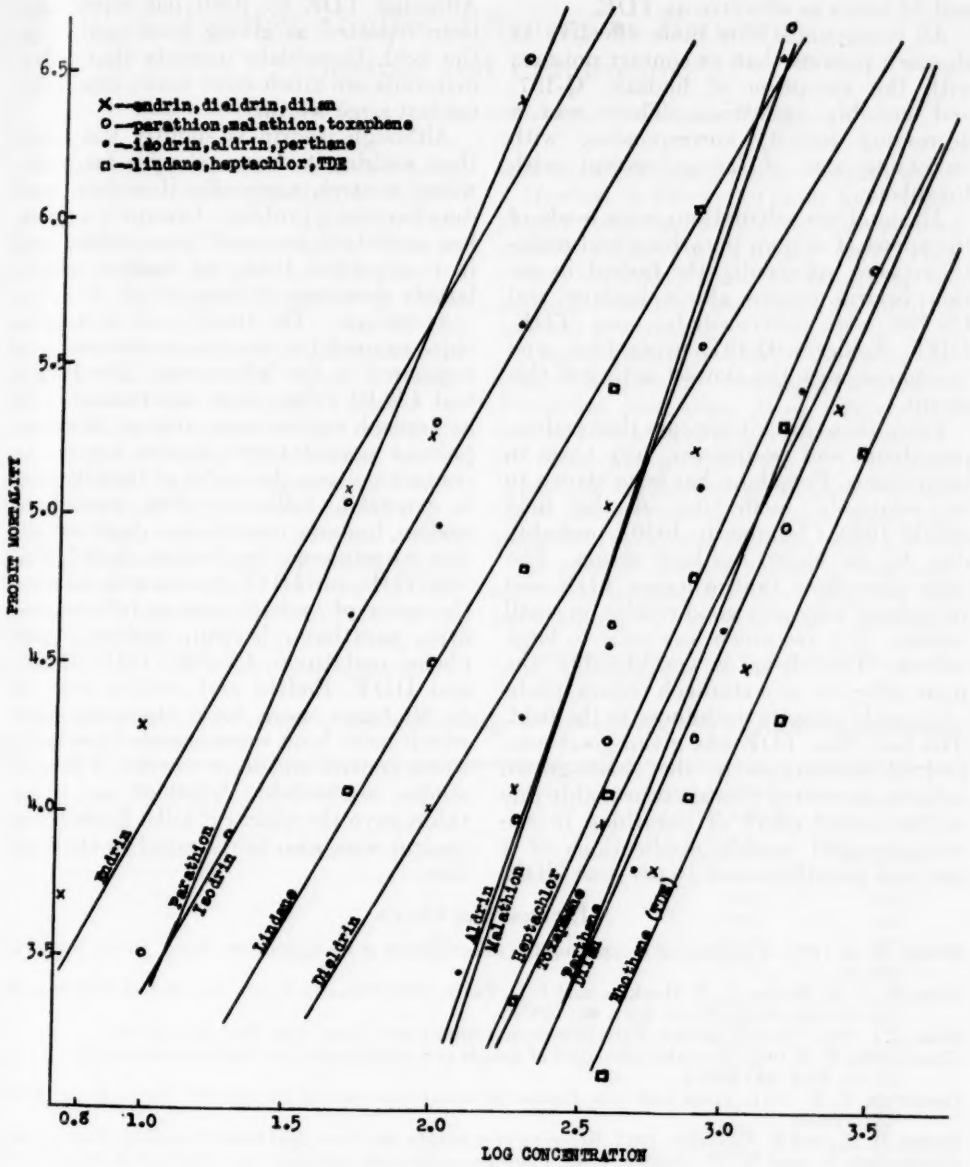

FIG. 1.—Dosage mortality curve of insecticides applied topically to 5th instar tobacco hornworms. Dilan is used to designate CS-708 and perthane for Q-137.

pared to endrin are shown in Table 1. A typical dosage-mortality curve for topical application made to 5th instar larvae is shown in figure 1.

Endrin was the most toxic of the compounds, both as a contact and stomach poison, and parathion and isodrin were nearly as toxic. Lindane, malathion, dieldrin, and aldrin were somewhat less effective. Toxaphene gave variable results according to the size of the larva and action of the poison but in general was about as toxic as malathion. Heptachlor, Q-137, CS-708, TDE, and DDT were considerably less effective than the other compounds tested.

In general, endrin was about 2–3 times as effective as parathion and isodrin, 30 times as effective as toxaphene and malathion, 50 times as effective as CS-708

and 75 times as effective as TDE.

All compounds were more effective as stomach poisons than as contact poisons, with the exception of lindane, Q-137, and possibly malathion. There was a decreasing toxicity corresponding with increasing size of larvae, except with toxaphene.

Although no calculations were made of the speed of action, parathion and malathion were apparently the fastest in action; isodrin, endrin, aldrin, lindane, and CS-708 were intermediate; and TDE, DDT, dielderin, Q-137, heptachlor, and toxaphene were the slowest acting of this group.

From these data it appears that endrin, parathion, and isodrin are very toxic to hornworms. Parathion has been shown to be relatively ineffective in the field (Stahl 1949, Chamberlin 1950), probably due to its short residual action. The data also show that whereas TDE and toxaphene may give good results on small worms, they are much less toxic to large worms. Toxaphene is considerably the more effective as a stomach poison, probably explaining its usefulness in the field. The fact that TDE has given good control of hornworms in the shade-grown tobacco district of Florida is probably due to the added effect of parathion in the recommended weekly applications of 1 per cent parathion and 10 per cent TDE. Although TDE by itself has repeatedly been reported as giving good control in the field, these data indicate that other materials are much more toxic, especially against large worms.

Although isodrin is slightly less toxic than endrin, it shows promise for hornworm control, especially if endrin residues become a problem. Isodrin is a much less persistent material than endrin, and it is expected that the residue would largely disappear during curing.

SUMMARY.—The toxicity of 13 insecticides against the tobacco hornworm was compared in the laboratory. The LD-50 and LD-90 values were determined both as topical applications and as stomach poisons against three sizes of larvae. As contact poisons the order of toxicity was in general as follows: endrin, parathion, isodrin, lindane, malathion = dieldrin = aldrin = toxaphene, heptachlor, Q-137, CS-708, TDE, and DDT. As stomach poisons, the order of toxicity was as follows: endrin, parathion, isodrin, lindane, toxaphene, malathion, CS-708, TDE, Q-137, and DDT. Endrin and isodrin were 20 to 80 times more toxic than materials which have been recommended for hornworm control and seem worthy of further studies in the field. Parathion and malathion gave the quickest kills. Endrin and isodrin were also fairly rapid in their action.

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Further Studies of Synergism Between Nicotine and Pyrethrum

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Results of preliminary tests indicating that nicotine and pyrethrum applied jointly show evidence of synergism have been published (Turner 1951). The insecticides were applied by injection to adults of the large milkweed bug, *Oncopeltus fasciatus* (Dall.). In three of the four tests the combination of pyrethrum and nicotine produced a higher mortality than expected on the basis of similar action, sufficient evidence for synergism according to Wadley (1945). In a test in which lots of bugs were injected with nicotine followed by pyrethrum at daily intervals, a high mortality occurred when pyrethrum followed nicotine in 24 hours. Intervals of 2 to 4 days between the two resulted in a substantially lower mortality. When pyrethrum was injected first, and nicotine from 1 to 4 days later, mortality was no larger than from pyrethrum alone.

Hewlett & Plackett (1952) have interpreted these same data on the basis of similar action, and Beard (1952) has noted, correctly, that the results of the multiple injection test could be additive and not synergistic.

Turner and Bliss (1953) extended the study by using the dipping technique on *Triboleum castaneum* Hbst. When the two materials were applied simultaneously, there was no evidence of synergism. When the application of nicotine was followed by pyrethrum $\frac{3}{4}$ hour later, the evidence for synergism was strong.

Because of the importance of the concept of synergism, a further study of the joint action of nicotine and pyrethrum

[1] The assistance of Mrs. Nancy W. Wheeler and Mrs. Joan T. Curtiss is gratefully acknowledged.

Table 1.—Summary of results of injection of large milkweed bugs with nicotine and pyrethrum applied singly and jointly.

Separate Applications (Per Cent)				Joint Applications (Per Cent)		
Nicotine[1]	Mortality[2]	Pyrethrum[1]	Mortality[2]	Nicotine[1]	Pyrethrum[1]	Mortality[2]
.4	83	.014	85	.2	.0035	100
.28	75	.01	81	.14	.0025	90
.2	58	.007	40	.1	.0018	56
.14	40	.005	16	.07	.0012	27
				.1	.005	98
				.07	.0035	83
				.05	.0025	73
				.035	.0018	54
.4	92	.014	90	.14	.007	96
.28	96	.01	69	.1	.005	98
.2	59	.007	37	.07	.0035	89
.14	33	.005	42	.05	.0025	62
				.035	.0017	47
.4	85	.014	83	.14	.0025	92
.28	71	.01	73	.1	.0017	71
.2	44	.007	32	.07	.0012	25
.14	15	.005	25	.05	.0009	29
				.035	.0006	37
.4	81	.014	96	.1	.007	100
.28	62	.01	77	.07	.005	100
.2	44	.007	54	.05	.0035	90
.14	21	.005	40	.035	.0025	81
				.025	.0017	52

[1] Per cent by weight.
[2] Each percentage mortality was obtained from 48 insects; 4 lots of 12 each.

has been made. Four series of injections into adults of the large milkweed bug were completed, using the two materials alone and jointly in five different ratios. In each test there were four lots of 12 bugs injected with each dosage. The results of these tests are summarized in table 1.

If synergism is present, the mortality following a joint application must be significantly greater than that predicted for other types of joint action, based on the separate dosage-mortality curves for the two materials used alone. Bliss (1939) considers the other types to be similar and independent joint action. Similar joint action is the simpler of the two to test. From the parallel log-dosage-mortality curves of the two ingredients, relative toxicity can be determined. Given this factor, the dosage of mixtures can be converted into units of one of the two components, and the mortality "predicted" from the curve for that component. Wadley (1949) has described a graphic method for comparing this predicted mortality with that observed from the joint application.

Table 2.—Calculation of the data in table 1 by the method of Wadley (1945).

Per Cent Nicotine	Nicotine Equivalent of Pyrethrum	Total Per Cent Nicotine	Mortality	
			Expected	Observed
.2	.104	.304	75	100
.14	.072	.212	58	90
.1	.050	.15	40	56
.07	.035	.105	24	27
.1	.147	.247	66	98
.07	.104	.174	48	83
.05	.072	.122	31	73
.035	.05	.085	16	54
.14	.165	.305	88	96
.1	.118	.218	70	98
.07	.083	.153	44	89
.05	.058	.108	21	62
.035	.040	.075	6	47
.14	.076	.216	46	92
.1	.053	.153	23	71
.07	.037	.107	8	25
.05	.026	.076	2	29
.035	.018	.053	0.3	37
.1	.256	.356	76	100
.07	.179	.249	56	100
.05	.125	.175	35	90
.035	.088	.123	17	81
.025	.061	.086	5.5	52

Preliminary examination of the data in table 1 was made by obtaining the nicotine equivalent of pyrethrum and interpolating on the nicotine curve for the "expected" mortality (Table 2). Comparison with observed mortalities showed substantial differences in favor of the observed, except in the lowest dosage of the first test. In this test the curve for the mixture plotted according to nicotine equivalents was not parallel with the curve for nicotine. The two would intersect at about probit 4.00 (16 per cent mortality), and at a dosage of .06 per cent nicotine. Obviously the closer the dosage used to the point of intersection, the lower the difference between the two would be. The reason for this lack of parallelism is unknown. The curves for the other four combinations were parallel with the curve for nicotine. Curves for the four other combinations yielded the following log ratios:

Test No.	*Log Ratio*
1b	.4
2	.24
3	.23
4	.48

The log ratios were from 4 to 8 times the estimated standard error, and the evidence for synergism very strong. Turner & Bliss (1953) found that in some cases independent action would result in higher mortality than similar action. The differences were not great, however, and there seemed to be no reason to make a more thorough statistical study.

Effect of Ratio of Nicotine to Pyrethrum.—The basic design of these experiments can be seen by an examination of the dosages in table 1. A dosage of nicotine was chosen such that it would produce mortality equal to that of a given dosage of pyrethrum. The factor $\sqrt{2}$ was used to construct a dosage series of each toxicant. The combinations were selected from the lower dosages of the materials used alone, because synergism was postulated. Since the mortality from the materials used alone was not always equal, the dosage ratios in the combinations were not exactly as planned. Perhaps the clearest way to show the relationships is by means of the equivalent dosages shown in table 2. When these combinations were plotted according to the nicotine equivalents, and compared with curves for nicotine alone, the results were

Table 3.—Summary of results of injection of large milkweed bugs with nicotine and pyrethrum applied separately and jointly.

Separate Applications (Per Cent)				Joint Applications (Per Cent)		
Nicotine	Mortality[1]	Pyrethrum	Mortality[1]	Nicotine	Pyrethrum	Mortality[1]
.4	98	.014	79	.025	.0035	62
.28	87	.01	54	.0175	.0025	27
.2	73	.007	35	.0125	.00175	12
.14	52	.005	19	.0088	.00125	6
				.035	.0025	50
				.025	.00175	21
				.0175	.00125	6
				.0125	.00088	2
.4	98	.014	85	.1	.0035	96
.28	94	.01	60	.07	.0025	87
.2	73	.007	48	.05	.00175	50
.14	50	.005	23	.035	.00125	46
				.175	.00125	88
				.125	.000875	54
				.0875	.000625	25
				.0625	.000438	12
.4	90	.014	92	.165	.0025	96
.28	81	.01	67	.115	.00175	71
.2	42	.007	42	.0825	.00125	54
.14	46	.005	27	.0575	.00088	31

[1] Each percentage mortality was obtained from 48 insects; 3 lots of 16 each.

as follows:

Ratio of Nicotine to Pyrethrum[1]	*Degree of Synergism on Basis of Nicotine*
2:1	2.0[2]
1:1.5	2.3
1:1.18	1.95
2:1	2.1
1:2.56	3.0

[1] Basis of nicotine equivalent.
[2] At highest dosage (curves not parallel).

Thus when the ratio of nicotine was 2 to 1 (on an equivalent toxicity basis) the dosage required was about half that estimated on the basis of similar action. The range of ratios in this test was not very large, but the highest degree of synergism occurred when there was about 28 per cent nicotine in the mixture (ratio 1:2.56).

In order to extend the range of ratios, another test was made. On the basis of curves drawn for all the data for nicotine and pyrethrum applied separately in table 1, dosages were selected to provide the following ratios:

Nicotine	*Pyrethrum*
10%	90%
25	75
50	50
75	25
90	10

All the calculations were based on dosage for equal control. Because synergism was expected, the amounts in the highest dosage of each ratio were scaled down to provide mortality less than 100 per cent. The results of the test have been summarized in table 3.

The data for nicotine and pyrethrum applied separately were used to calculate the amount of nicotine in terms of pyrethrum, and the observed mortality of the mixtures plotted on the logarithmic probability grid. The degree of synergism was determined by dividing the amount of pyrethrum required to produce 50 per cent mortality by the amount in equivalent of the mixture to produce the same effect. The results were as follows:

Concentration		*Ratio*		*Degree of Synergism*
Nicotine	*Pyrethrum*	*Nicotine*	*Pyrethrum*	
.025	.0035	10	90	1.73
.035	.0025	25	75	1.76
.1	.0035	50	50	2.44
.165	.0025	75	25	1.7
.175	.00125	90	10	1.2

Thus the degree of synergism was largest when the two materials were used in what were calculated to be equitoxic dosages. Synergism from three other

ratios was about equal, and when 90 per cent nicotine and 10 per cent pyrethrum were combined, there was little evidence of synergism. These results do not conform entirely to those of the test reported on page 221. The importance of this discrepancy cannot be determined from the data at hand.

Sakai *et al.* (1951) and Sakai *et al.* (1951) have published results of tests on *Drosophila* and on aphids using pyrethrum alone, nicotine alone, and the two mixed in a series of 9 mixtures varying from 90 per cent nicotine and 10 per cent pyrethrum to 10 per cent nicotine and 90 per cent pyrethrum. On *Drosophila* they found a "potency" of almost 2 when the mixture contained 80 per cent or 90 per cent pyrethrum and 20 per cent or 10 per cent nicotine. There was no synergism or actual antagonism when the amount of nicotine exceeded 30 per cent. On aphids mixtures containing 50 per cent or more of pyrethrum were synergistic, with a "potency" of 2 when there was 60 per cent to 80 per cent pyrethrum. Their "potency" was obtained by dividing the percentage mortality observed by the mortality expected on the basis of similar action.

Such a "potency" could be calculated from table 3, but would be more accurate on the basis of probits than of unconverted percentages. In any case, the results obtained on milkweed bugs do not conflict seriously with those of Sakai *et al.* (1951).

EFFECT OF INTERVAL BETWEEN APPLICATIONS.—In tests reported previously (Turner 1951), there was an indication that nicotine "conditioned" the insects for pyrethrum. An experiment was designed to provide further data on this possibility. Fifty adult milkweed bugs were injected with .14 per cent nicotine and .0035 per cent pyrethrum. Eight lots of 50 insects each were injected with .14 per cent nicotine, and eight with .0035 per cent pyrethrum. At intervals of 6, 24, 48 and 72 hours after the first injection, one lot previously injected with nicotine was treated with pyrethrum and vice versa. At intervals of 6, 24 and 48 hours after the first injection, one lot previously injected with nicotine was treated again with nicotine, and pyrethrum was injected into bugs previously treated with pyrethrum. A count of total mortality was made six days after the first treatment. The results are given in table 4. The mortality from .14 per cent nicotine was 20 per cent, and from .0035 per cent pyrethrum, 14 per cent. The two applied simultaneously produced 98 per cent mortality. When nicotine was followed by pyrethrum in 6 hours, mortality was 96 per cent, and longer intervals between treatment reduced mortality consistently. When pyrethrum was followed by nicotine in 6 hours, the mortality was only 72 per cent, and at longer intervals mortality was about additive.

Nicotine followed by nicotine within 6 hours produced a higher mortality than delay of 24 and 48 hours. This mortality, 68 per cent, was about as expected from a dosage of 0.28 per cent nicotine (Table 1). This effect was lost to a large extent after 24 hours, which would indicate a substantial recovery from the effects of nicotine within that period.

Pyrethrum followed by pyrethrum produced about the same mortality regardless of the length of time between treatments. The mortality was, however,

Table 4.—Effect of time between injection of nicotine and pyrethrum, large milkweed bugs.

INTERVAL BETWEEN TREATMENTS		PER CENT MORTALITY
.14 per cent nicotine	followed by	.0035 per cent pyrethrum
0		98
6 hrs.		96
24 hrs.		76
48 hrs.		54
72 hrs.		56
.14 per cent nicotine		20
.0035 per cent pyrethrum	followed by	.14 per cent nicotine
0		98
6 hrs.		72
24 hrs.		36
48 hrs.		38
72 hrs.		28
.0035 per cent pyrethrum only		14
.14 per cent nicotine	followed by	.14 per cent nicotine
6 hrs.		68
24 hrs.		43
48 hrs.		33
.0035 per cent pyrethrum	followed by	.0035 per cent pyrethrum
6 hrs.		42
24 hrs.		48
48 hrs.		40

Table 5.—Summary of results of injection of large milkweed bugs with nicotine and allethrin applied singly and jointly.

Separate Applications (Per Cent)				Joint Application (Per Cent)		
Nicotine	Mortality[1]	Allethrin	Mortality[1]	Nicotine	Pyrethrum	Mortality[1]
.4	90	.07	96	.1	.025	94
.28	67	.05	71	.07	.018	58
.2	58	.035	60	.05	.013	37
.14	23	.025	31	.035	.009	25
				.025	.006	8

[1] Each percentage mortality was obtained from 48 insects; 4 lots of 12 each.

far higher than anticipated on the basis of relatively quick recovery from pyrethrum.

There is undoubtedly a different reaction when nicotine is followed later by pyrethrum and pyrethrum followed by nicotine. Perhaps it is simply the result of a different rate of detoxification of the two materials in the body of the insects, as postulated by Turner & Bliss (1953). Nicotine obviously persists longer than pyrethrum, as evidenced by the decrease in toxicity when nicotine was followed by nicotine, and the persistence of high toxicity for 24 hours when nicotine was followed by pyrethrum.

No explanation of the toxicity of pyrethrum followed by pyrethrum can be given. Mortality seems as large as would be expected if the dosages were additive for as long as 48 hours. It is also higher than expected if each injection killed only 14 per cent of the insects.

EFFECT OF NICOTINE ON TOXICITY OF ALLETHRIN.—One test for synergism between nicotine and allethrin was completed. The method and design of the experiment were very similar to the tests using pyrethrum. The results have been summarized in tables 5 and 6. There was obviously good evidence for synergism. When calculated by Wadley's (1949) method, the slope was 5, and the log ratio 0.21, with a standard error of 0.05. The degree of synergism was about 1.5, or substantially less than between nicotine and the pyrethrins. The fact that synergism occurred is not at all unexpected because allethrin is very closely related chemically to the active principles in pyrethrum.

DISCUSSION AND SUMMARY.—The results of the tests reported here confirm those of preliminary tests (Turner 1951) which indicated that nicotine and pyrethrum applied jointly showed evidence of synergism. The degree of synergism varied from almost 2.0 to 3.0 on the basis of the amount required to produce equal mortality. The greatest degree of synergism resulted when 1 part of nicotine was combined with 2.56 parts of pyrethrum, the "parts" being measured by the amount necessary to produce equal mortality.

In a test of a wider range of ratios between nicotine and pyrethrum, a 50–50 mixture produced the highest degree of synergism. Least synergism resulted from a combination of 90 per cent nicotine and 10 per cent pyrethrum.

In four out of five tests, the dosage-response curves for nicotine and pyrethrum combined, based on nicotine equivalent, were parallel with curves for the separate ingredients.

Results of tests in which the interval between injection of the two materials was

Table 6.—Calculation for Synergism from Data in Table 5 (Wadley 1945).

Per Cent Nicotine	Nicotine Equivalent of Allethrin	Total Per Cent Nicotine	Mortality		Synergism
			Expected	Observed	
.1	.149	.249	58	94	+++
.07	.104	.174	41	58	+
.05	.07	.12	20	37	++
.035	.05	.085	9	25	++
.025	.035	.06	3	8	+

varied indicated that the toxicity of pyrethrum following nicotine was greater than of nicotine following pyrethrum. Toxicity of nicotine following nicotine was clearly additive in 6 hours, and decreased rapdily at 24 and 40 hours. Toxicity of pyrethrum following pyrethrum seemed stable regardless of time between treatments. Further work will be necessary to clarify the reason for this. The former conclusion (Turner 1951) that nicotine "conditioned" the insects for pyrethrum is apparently incorrect. The results can be explained just as well on the basis of a longer period of effectiveness for nicotine.

These tests were not designed to show the reasons for the synergism between nicotine and pyrethrum. It seems obvious, however, that it is not the result of negative correlation of susceptibility to the two materials (Plackett & Hewlett 1948). Mortality was far larger than could be accounted for by this theory.

As might be expected, there was evidence of synergism between nicotine and allethrin.

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Oviposition by the Poultry Bug

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Populations of the poultry bug, *Haematosiphon inodorus* (Duges),[1] may reach large numbers in a relatively short period of time as pointed out in a previous paper (Lee 1954). Records of 1,425 and 1,778 bugs taken from two barn owl nests were given. Townsend (1893) also mentioned that this species may increase to great numbers in poultry houses. The oviposition study presented here was made because this insect is of interest to poultry raisers in certain sections of the southwestern United States and because a knowledge of the potential population is important in control of this pest.

OVIPOSITION POTENTIAL.—Last instar nymphs were fed and separated into individual vials so that the sexes would remain separate when the nymphs emerged to the adult stage. As the adults emerged, a male was placed with a female; each pair was kept separate from other pairs by putting them in vials, 2 inches high by 0.5 inch in diameter. A strip of blotting paper the length of the vial was placed inside the container to support the bugs and to allow the female a suitable place on which to lay eggs. Eggs may be laid on the glass bottom of the vial by females not being supported by the paper; however, the paper strips greatly aided in the collection and counting of eggs. Clean

[1] (Hemiptera: Cimicidae.

Table 1.—Egg laying by single pairs of *Haematosiphon inodorus* (Duges) at 25.5 to 29° C. and 58 to 64 per cent relative humidity.

Number of Eggs Laid Every Second Day After Pairing															Eggs Laid	
2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	Total	Average per Day
		6	10	3		2	x[1]								21	3.50
				2	1							x			3	.33
			2	6	2			x							10	1.66
		9	7	7		5	2	6	2	x					38	4.22
			2	7	2	4	7	9	3		2	12	3	x5	56	4.66
			9			3		1	x						13	1.86
		13	1	13	4	12	x1								44	7.33
				14	7	11	x1								33	8.25
	5	14	3	14	5	4	4	16	4	5	8	14	x		96	7.38
	12	8	3	2	14	x									39	6.50
		7		8	4	4	x								23	3.83
	11	7		8	x3										29	5.80
	12	12	x3												27	9.00
			3	5		3		2		9	3	5		1	31	2.58
		12	3	2	3	9		x							29	4.14

[1] x indicates date female died.

strips of paper were used after each collection of eggs was made. Nylon cloth having 85 by 67 threads per inch was used to cover the container; the bugs were able to feed through the cloth on chickens.

The insects were allowed to feed on the day they were paired; they were also given the opportunity to feed 48 hours after having been placed together. This gave a second chance to feed to those which had refused the first meal. Thereafter, each pair was allowed to feed every fourth day. All experiments presented in this paper were conducted at 25.5° to 29° C. and 58 to 64 per cent relative humidity.

Because a study was being conducted simultaneously on other phases of the life history of *Haematosiphon inodorus*, a large number of individuals were not available for this experiment. However, it is felt that the data gathered from the pairs used may be studied statistically to at least show the trend in the egg production of this species. Methods and formulae discussed by Cazier and Bacon (1949) were used in this paper.

Fifteen males were paired with as many females as described above. The eggs were counted every 48 hours after pairing, and the number of eggs laid was recorded as in table 1. Only normal appearing eggs were counted; a few shriveled egg shells were seen but not included in the count.

The average number of eggs laid per day is based on the time from the first day of oviposition to the day of death of the female. It has been found from previous study that males live longer than females; the shorter life span of the female is undoubtedly due to her egg laying. The average number of eggs laid per day was 4.43 ± 2.51 eggs.

Out of 76 eggs used in the life history study mentioned above, 72 eggs, or 94.7 per cent, hatched. Of the 72 first instar nymphs which hatched, 41 individuals, or 56.9 per cent, reached adulthood. Therefore, 53.9 per cent of the 76 eggs used eventually became adults. It is obvious that a poultry house or other suitable habitat might, under proper conditions, soon become infested with large numbers of this species.

AUTOGENIC REPRODUCTION.—That *Haematosiphon inodorus* is capable of autogenic reproduction was shown by the following experiment. Fourteen adult males and 14 adult females, each of which had molted to the adult stage in a separate vial, were put together into one large vial. The bugs were not allowed to feed, and the vial was checked each day for eggs. On the fourth day after the experiment was begun, 11 eggs were laid; on the fifth day, 1 egg was laid. No more eggs were laid; all the females died shortly therafter. Ten of the 12 eggs hatched. Indications are that it is possible for inseminated *H. inodorus* females to lay fertile eggs using the nutrition stored

in the body before the last molt.

INSEMINATION NEEDED FOR OVIPOSITION.—Adult females must be inseminated to lay eggs. Eight females, which had molted to adults in individual vials within 48 hours, were placed together and fed. No males were admitted to the container. The group was allowed to feed and was checked for eggs every second day. Sixteen days after the experiment started, one female was found dead. During the time the females were kept separate from males, no eggs were seen; although as indicated in table 1, fed females in the presence of males laid eggs within 4 to 10 days after having been paired with males. Eggs were laid by the fourth day even by females in the experiment on autogenic reproduction.

Twenty-five days after the experiment started, seven well-fed, adult males were paired with the females and put in vials, each containing a male and female. The vials were checked each 48 hours. Four days after having been paired with males, five of the seven females each laid an average of 6.4 eggs. On the eighth day after having been put with males, the other two females laid two eggs and one egg respectively.

SUMMARY.—Because of a substantial egg output, 4.43 eggs per day per female, and because of a good percentage of adults from eggs layed, 53.9 per cent, populations of *Haematosiphon inodorus* (Duges) can be expected to reach high numbers under suitable conditions. It is possible for inseminated female adults to reproduce without having had a blood meal since the last molt. It is impossible for adult females which have not been inseminated to lay eggs.

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Further Studies on the Treatment of Border Vegetation for Melon Fly Control[1]

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The basis for the treatment of border vegetation as a means of controlling the melon fly, *Dacus cucurbitae* Coq., lies in the behavior of the insect (Nishida & Bess 1950). Gravid flies were found to enter the field to oviposit during the day and did not remain among host crop plants for any extended period of time. Furthermore, the greatest number of flies capable of damaging the crop was found not within the field, but outside the field among wild vegetation. As a consequence, it was reasoned that control might be obtained if treatment were applied to the wild plants with which the adults are closely associated rather than to the crop to be protected. That such treatments are effective was shown by applying insecticides on border vegetation by means of a mist blower (Nishida & Bess 1950, Ebeling *et al.* 1953).

The present study was made to determine whether successful control of the melon fly can be obtained by applying insecticides with conventional-type sprayers on border vegetation. The question of whether such equipment could be used instead of a mist blower is one of practical importance because, if control could be obtained, farmers could profitably use sprayers already on hand.

METHODS.—These experiments were carried out in cucumber and tomato fields in cooperation with growers who made applications with the type of power spray-

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[2] The suggestions and criticisms of Dr. H. A. Bess and the cooperation of growers are gratefully acknowledged.

ers which they owned. The sprayers used by the farmers were manufactured by various companies and differed in their capacity to develop pressure and to deliver the spray; however, all equipment was capable of developing a pressure of at least 250 p.s.i. at the pump and delivering 5 gallons of spray per minute.

The border treatments were made by directing the spray from the edge of the field into the bordering vegetation, usually during the early morning hours. The insecticides used in all border treatments was parathion, a material which is highly toxic to the melon fly both as residual and space sprays (Ebeling 1953).

The effectiveness of the treatments was based on the percentage of infested fruits in the samples taken from various parts of the field. The size of the cucumber fruits sampled ranged from 3 to 10 cm. in length, and that of the tomato fruits 2 to 4 cm. in diameter. The total number of fruits ranged from 188 to 3,600. In establishing a criterion of damage, all fruits which showed any evidence of oviposition puncture were considered infested regardless of whether or not they contained eggs or larvae. As a basis for comparison parallel data were taken from both border-treated fields and the untreated fields designated as check fields. The plants in the border-treated fields were not sprayed except for the control of other pests, for example, aphids on cucumber plants and corn earworms on tomato.

It was not feasible to use randomized field-plot techniques in these experiments because of the small size of the available fields and the intra-field movements of the fly (Ebeling *et al.* 1953). Rather than subdividing a field into plots, the entire field was considered an experimental unit. The use of individual fields as experimental units made it necessary to limit the number of replications. This limitation, although inevitable, is an obvious weakness in the procedure as there is usually considerable variation in fly population between fields due largely to differences in the kind and condition of the vegetation present and also to the frequency at which susceptible crops were grown in the immediate vicinity. However, the fly population in any individual field is usually high enough to cause appreciable damage in the absence of satisfactory control practices.

EXPERIMENT ON CUCUMBERS.—Five fields with areas ranging from one-fourth to 1 acre were involved in this study. The bordering vegetation of two fields, designated as fields D and E, was sprayed with parathion at a concentration of 1 pound of a 25-per cent wettable powder per 100 gallons of water at intervals of roughly twice a week from the time the runners appeared up to the time of harvest. During the harvest period the frequency of treatment was reduced to once a week.

The kind of vegetation bordering these two fields was typical of many lowland areas on Oahu where cucumbers are grown commercially. Field D was bordered on three sides by a corn field. The vegetation along the fourth side consisted of a narrow strip of miscellaneous weeds along a roadside. In field E, a few volunteer corn plants were present, but the vegetation bordering it consisted of wild plants, chiefly fuzzy rattle-box (*Crotolaria incana* L.,) spiny amaranth (*Amaranthus spinosus* L.) and castor bean (*Ricinus communis* L.).

The remaining three fields, designated as fields A, B, and C in which no border treatments were made, were check fields. The cucumber plants in these fields were sprayed with parathion at a concentration of $\frac{1}{4}$ to $\frac{1}{2}$ pound of a 25-per cent wettable powder per 100 gallons of water. The frequency of application varied from twice a day to once every 3 days.

The infestation data obtained from border-treated and control fields are shown graphically in figure 1. It is evident that the percentage of stung fruits in the border-treated fields was considerably lower than that in the control fields. In

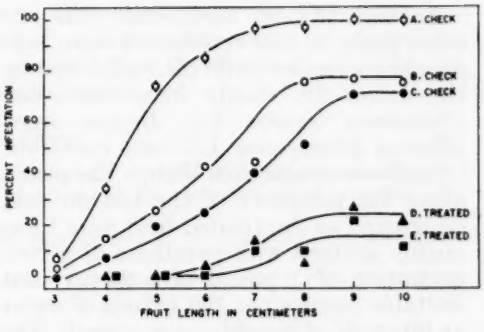

FIG. 1.—Comparison of the infestation of cucumber fruits of various sizes between border treated and check fields.

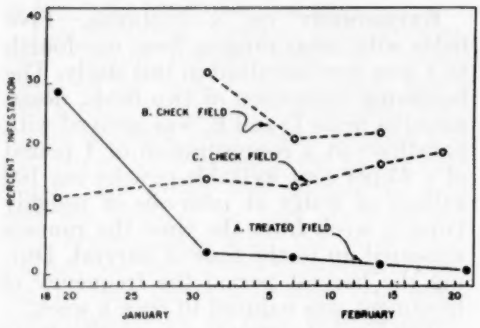

FIG. 2.—Comparative levels of tomato fruit infestation between border treated and check fields during January and February, 1951.

the check fields even the very young fruits were infested, but in the treated-field infestation did not take place until the fruits were 6 to 7 cm. long. It was observed that in the check fields where the cucumber crop was treated the plants showed evidences of insecticidal injury, particularly in fields where too frequent applications were made. The foliage of the injured plants appeared grayish white, and the fruiting period of these plants was very much shortened. Although no yield data were obtained, it was apparent that, because of the combined effect of fly damage and the adverse effect of the insecticide on the plant, the yield of plants in the check fields was less than that in the border-treated fields. It should be mentioned, however, that although the data show that the percentage of stung fruits was as high as 100 per cent in one of the check fields, the farmer did not lose that proportion of his crop because not all fruits decompose when stung and, furthermore, fruits with oviposition scars are marketable even though they are inferior in quality.

EXPERIMENT ON TOMATOES.—The tomato fields in this experiment were bordered by succulent wild plants favored by the melon fly, chiefly fuzzy rattle-box (*Crotolaria incana* L.), Jimson weed (*Datura stramonium* L.), and cocklebur (*Xanthium saccharatum* Wall.). The plants along the periphery of the tomato field designated as the treated field were thoroughly sprayed with parathion at a concentration of 1 pound of a 25-per cent wettable powder per 100 gallons of water at intervals of roughly once a week. The check fields received no border treatment, but the tomato plants were sprayed with DDT at irregular intervals ranging from twice a week to once in 10 days.

At the time this study was initiated there were young fruits on the plants, and data on infestation were taken before the first border treatment and four times thereafter from the treated field and check field C. Only three records were taken from check field B.

The results presented in figure 2 show that prior to the initial treatment 27 per cent of the fruits sampled were infested in the treated field. The first two treatments reduced the infestation to 3 per cent. The four treatments made thereafter caused a slight but consistent decline in the percentage of damaged fruits. In check field C, the initial infestation was lower than that of the treated field, but it showed no decline. In check field B, the percentage of infestation declined, but it remained consistently higher than the treated field.

At various intervals throughout the experimental period, counts were made on the number of adults that were seen along the border-treated field. On January 17, 1951, prior to the first treatment, 75 adults were counted. One week after the first treatment only three adults were observed. Similar counts made subsequently at various intervals showed that up to January 29 the number of adults along the 200 feet of border was less than four. On January 31 the number suddenly increased to 15 adults, but the treatment made on the following morning brought the adult count down to two. From then on, the number of adults observed was never greater than two per 200 feet of border plants.

DISCUSSION.—Previous studies have shown that effective control of the melon fly can be obtained by border treatment by means of a mist blower (Nishida & Bess 1950, Ebeling *et al.* 1953). The results of this study show that the melon fly can also be controlled by the application of a suitable insecticide with conventional sprayers on wild plants. However, field experience as well as experimental work thus far has indicated that control cannot be obtained when treatments are made on the crop to be protected, regardless of the type of equipment used. This anomalous situation appears to be related to the behavior of the melon fly.

When insecticides are applied under

field conditions, melon flies may acquire lethal amounts of the sprayed material in two ways; they may acquire such materials by the droplets of spray landing on their bodies and by their own activities on treated surfaces. For example, the flies may acquire toxic residues by merely walking on treated surfaces. Toxic residues may also find entry into the bodies of the insect through their feeding habits. Melon flies regurgitate droplets of liquid and then the same droplets are taken in again. It is conceivable that if such actions take place on treated surfaces, the flies would be poisoned by the contaminated regurgitated material. Dew drops, honeydew, and plant exudations are ingested by adults; consequently, insecticides applied on plants on which the adults imbibe water and feed would be readily ingested. The habit of touching surfaces frequently with the proboscis might also be an activity by which melon flies may be poisoned by residues. Habits similar to these were observed by Boyce (1934) in the case of another tephritid fly, *Rhagoletis completa* Cresson.

The failure to obtain control when crop treatments were made was ascribed to the inability of the insect to "pick up" lethal amounts of the treated material (Ebeling *et al.* 1953). The adults which enter the field are generally gravid females, and they probably enter crop areas only to oviposit. Hence, they do not remain continuously on crop plants and also do not carry on activities such as regurgitating and feeding to such an extent on crop plants as they do among wild plants. Because of these differences in behavior, melon flies do not acquire as much of the insecticide applied on crop plants as they would when applications are made on wild plants.

In contrast to crop treatments, border treatments have been found to be very effective. The effective control obtained by the treatment of wild plants with which the adults are closely associated is due to the presence of large numbers of adults which may be readily killed by space action of the sprays applied. Residual action is also effective in such situations because the adults continue to remain in close association with the treated vegetation, carrying on various activities necessary for their survival, and in doing so they acquire toxic residues from the sprayed plants.

SUMMARY.—The use of conventional-type sprayers instead of the mist blowers previously used for border treatments in the control of the melon fly was investigated. In experiments carried out in cucumber and tomato fields, it was found that the melon fly can be controlled effectively by treating border vegetation with parathion at a concentration of 1 pound of a 25-per cent wettable powder per 100 gallons of water by means of conventional-type power sprayers. In experiments with both cucumbers and tomatoes the border-treated fields showed a markedly lower percentage of infested fruits than their corresponding check fields.

The ineffectiveness of crop treatment as compared to similar treatments on wild vegetation has been attributed to the behavior of the melon fly. Gravid females enter crop areas to lay eggs, consequently they apparently do not remain continuously on crop plants and also do not engage in activities such as feeding and regurgitating. Therefore, they do not acquire lethal amounts of the material applied on crop plants. On wild plants, however, the adults of both sexes and various ages are present in large numbers, and there they carry on various activities necessary for their survival. Insecticides are, therefore, most effective when applied on border wild plants because adults may be killed by space as well as by residual action.

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Altitude Tolerance of Normal and Infected Insects[1]

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The possibility that exogenous insects and their eggs lodged on the surface of aircraft may be transported accidentally into the United States represents an important military and public health problem. Several investigators have reported finding eggs of insects on the surface of aircraft at the end of a flight. Laird reported that between March and December 1951, 531 insects (representing 52 families and 9 orders) were collected from 111 out of 343 aircraft which arrived at Whenuapai Airport, Auckland, from abroad. Moth egg masses were likewise collected from the exterior of 32 aircraft from Fiji, Norfolk Island and Australia; these eggs were all viable on collection (White & Kirkpatrick 1949; Porter & Hughes 1950; Laird 1952).

The effects of cold on insects under normal atmospheric conditions have been studied by several investigators. The majority agree that temperatures below −20° C. for 2 hours are detrimental to most insects (Reaumur 1734; Bachmetjew 1901; Duval & Portier 1922; Bodine 1923; Payne 1926; Luyet & Gehenis 1940; Steinhaus 1949; Stemler & Hiestand 1951.)

No specific data is available in the literature pertaining to the concomitant effects of low temperature and correspondingly low atmospheric pressure on insects and their eggs and the relationship of these factors to the prevention of the transportation of insects and their eggs on the surface of aircraft. This communication deals with the effects of simultaneous low temperature and low atmospheric pressure on five species of insects.

MATERIAL AND METHODS.—Temperature and pressure conditions corresponding to various altitudes were simulated by means of a low temperature refrigerator with low pressure chamber constructed according to our own specifications by Scientific Specialties Corporation of Cambridge, Mass. (Figure 1.)

The refrigeration unit of the equipment is based on the cascade principle, consisting of two separate but simple systems operating at normal pressures with the use of capillary tubes and other characteristics of such a system. It contains a one-half horsepower unit in the first stage for *Freon 22* and a one-third horsepower unit in the second stage for ethane.

The low pressure chamber is mounted on top of the base unit. Inside dimensions of this chamber are 12×12×12 inches. It is provided with two interchangeable doors, one of which contains a thermopane window through which the insects, thermometer, and hygrometer can be seen. There is an adjustable vacuum regulation control. A partial vacuum of about 30 inches of mercury can be maintained in the chamber by means of a vacuum pump with automatic pressure regulating switches. Two separate valves are provided which permit dry air or room air to enter the vacuum system. The chamber can also maintain positive atmospheric pressures (15 to 30 pounds) at temperatures ranging from +37° C. to −85° C. The heater switch mounted below the thermostat operates an 80-watt heater around the breaker. This is to minimize sweating at the low temperatures and to thaw any ice around the cover to facilitate the removal of this after prolonged operation. To obtain extreme temperatures it may be necessary to switch this off. The pressure and temperature of the chamber are easily determined from gauges placed outside of the chamber on the front of the cabinet (Figure 1).

A small tube, about one-half inch in diameter, leads from the left side of the cabinet into the chamber. Both ends of the tube are provided with stopcocks (a metal stopcock outside of the machine and glass stopcock inside). This arrangement is made for the exchange of gases in the chamber whenever necessary, and it can also be used to check the inside vacuum with an outside auxiliary manometer (Figure 1).

This unit can be operated indefinitely by ordinary 110-volt AC current at −45°C. However, for special experiments, each lasting a few hours, temperatures as low as −85° C. can be maintained with the corresponding reduced pressures as en-

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[2] With technical assistance of Mr. Don Esplin.

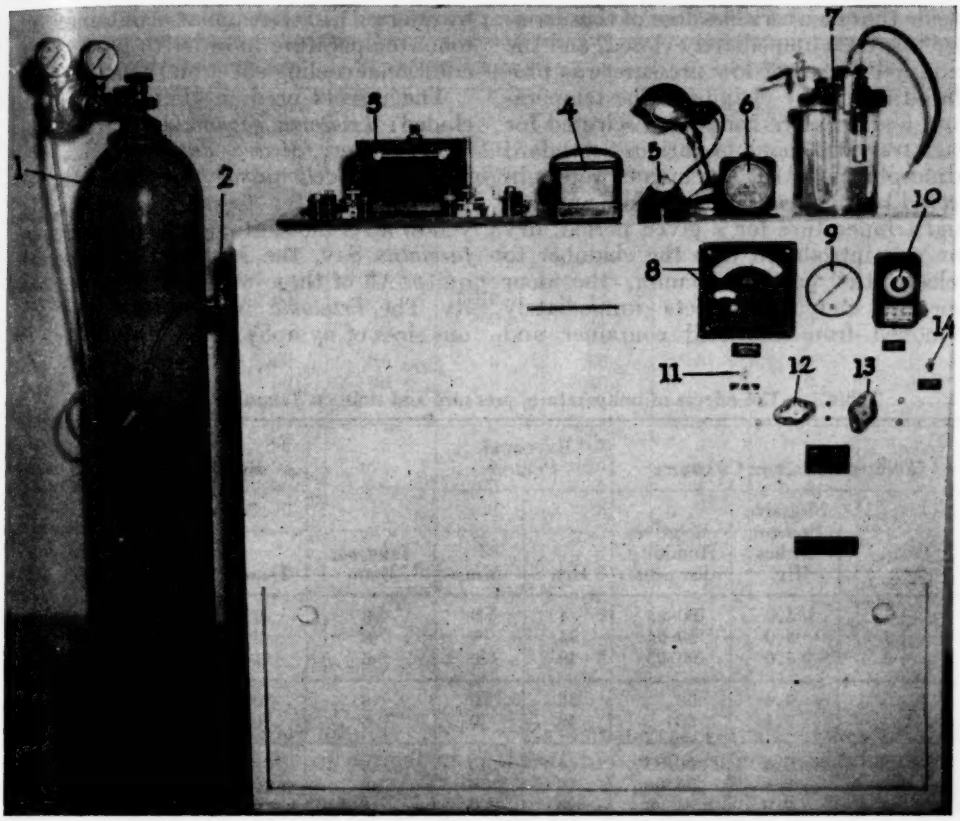

FIG. 1.—Refrigerator with Stratosphere Chamber, and Accessories.

1. Oxygen Tank
2. Auxiliary inlet
3. Door of Chamber
4. Hygrometer
5. Stop Watch
6. Interval Timer
7. Vacuum Jar
8. Thermometer and Temp. Control
9. Vacuum Gauge
10. Vacuum Control
11. Heater Switch
12. Vacuum Release (Room Air)
13. Vacuum Release (dry air)
14. Vacuum Circuit (Toggle Switch)

countered in the flight of aircraft at "standard atmosphere" or stratosphere. The overall dimensions of this equipment are 49 inches long×23 inches wide×41 inches high.

Measurement of humidity within the chamber at reduced temperatures and pressures was obtained by the use of a self-contained animal membrane-type hygrometer (4″×5″×3″). This instrument allowed readings of humidity with an accuracy of ±3 per cent at temperatures as low as −45° C. The hygrometer was placed inside the chamber and readings were taken through the thermopane window.

The chief difficulty encountered in the operation of this machine consisted of the manipulation of the heavy door which contained the thermopane window. This difficulty was solved by the construction of another door with adequate insulation and vacuum-tight seal which prevents frost and heat transfer. The lid of this door is fastened with hinges on the top of the chamber and can be opened and closed quickly and easily. It was constructed by the machine shop at the University of Texas Medical Branch in Galveston.

When the chamber was used for experimental work, a few small glass jars containing filter papers were placed in it. The air inside the chamber was then evacuated, and dry air was substituted in order to prevent frost inside the chamber. Then the chamber and glass jars were cooled to the desired temperature, after which the door was opened and the insects quickly placed in the cooled containers

inside the chamber. The door of the chamber was then immediately closed, and the required degree of low pressure was produced inside the chamber. The temperature and pressure conditions selected for each test correspond to various "standard atmospheres." After the insects were subjected to these conditions of low pressure and temperature for a given period, dry air was introduced into the chamber to release the partial vacuum, the door opened, and the insects immediately removed from the cold container and transferred to a similar container at room temperature in order to prevent an additional cooling effect on the insects.

The insects used in these studies included: *Triatoma gerstaeckeri* (Stål), the blood-sucker; *Musca domestica* L., the house fly; *Bdellonyssus bacoti* (Hirst), the tropical rat mite; *Aedes aegypti* (L.), the yellow fever mosquito; and *Culex quinquefasciatus* Say, the southern house mosquito. All of these were reared in captivity. The *Triatoma* used consisted of various sizes of nymphs and a few adults. All

Table 1.—The effects of temperature, pressure and time on *Triatoma gerstaeckeri*.

Conditions in the Chamber			Exposure Period			Effects on *Triatoma*		
						Number		
Temp. ° C.	Negative Pressure Inches Hg.	Relative Humidity (per cent)	Hrs.	Min.	*Triatoma* Used	Dead	Survived	Paralysis Noted
+5	5.0	90–95	4	0	6	0	6	—
+5	5.0	90–95	24	0	6	0	6	—
+5	5.0	90–95	48	0	6	1	5	—
0	7.4	90	36	0	6	0	6	—
0	7.4	90	48	0	6	0	6	—
−5	9.0	60–85	4	10	6	0	6	—
−5	9.0	85–90	16	0	6	0	6	—
−5	9.0	85–90	24	0	6	0	6	—
−5	9.0	90	36	0	6	0	6	—
−5	9.0	90	48	0	6	0	6	—
−10	11.5	80	1	0	6	0	6	—
−10	11.5	90	2	0	6	0	6	—
−10	11.5	85–90	4	0	6	1	5	+
−10	11.5	85–90	8	0	6	0	6	+
−10	11.5	85–90	12	0	6	1	5	+
−10	11.5	85–90	24	0	6	2	4	+
−15	13.0	85–90	0	15	6	0	6	−
−15	13.0	60–75	0	30	6	0	6	−
−15	13.0	60–75	1	0	6	0	6	+
−15	13.0	70	2	0	6	4	2	+
−15	13.0	60–75	4	0	6	6	0	−
−15	13.0	95–86	24	0	6	6	0	−
−20	14.6	40	0	30	6	0	6	−
−20	14.6	60	1	0	6	0	6	+
−25	16.2	80	0	15	6	0	6	−
−25	16.2	80	0	30	6	1	5	+
−25	16.2	80	1	0	6	5	1	+
−30	17.5	—	0	15	7	7	0	−
−44	21.0	52	1	0	3[1]	3	0	
−44	21.0	52	2	0	3[1]	3	0	
−54	23.0	—	0	15	5	5	0	—
−54	23.0	37–76	0	20	28	28	0	−

[1] The *Triatoma* used in these experiments were infected with *Trypanosoma cruzi*. After exposure time, the *Triatoma* were found dead, but the flagellates were still viable and active.

Table 2.—The effects of temperature, pressure and time on *Musca domestica*.

Conditions in the Chamber			Exposure Period		Flies Used	Effects on Flies		
						Number		
Temp. °C.	Negative Pressure Inches Hg.	Relative Humidity (per cent)	Hrs.	Min.		Dead	Survived	Paralysis Noted
+5	5.0	85–90	4	0	4	0	4	–
0	7.4	90	36	0	7	0	7	–
0	7.4	90	48	0	10	0	10	–
−5	9.0	60–85	4	10	11	0	11	–
−5	9.0	85–90	16	0	11	1	10	–
−5	9.0	85–90	24	0	9	0	9	–
−5	9.0	90	36	0	26	0	26	±
−5	9.0	90	48	0	10	0	10	±
−10	11.5	90	1	0	11	0	11	–
−10	11.5	90	2	0	7	0	7	–
−10	11.5	85–90	4	0	10	9	1	±
−10	11.5	85–90	8	0	9	9	0	–
−10	11.5	85–90	12	0	8	8	0	–
−15	13.0	—	0	15	6	6	0	–
−15	13.0	70	2	0	7	7	0	–
−30	17.5	—	0	15	6	6	0	–
−54	23.0	—	0	15	6	6	0	–

other arthropods used were adults.

In each test, from 3 to 28 normal insects were placed in a glass container. The containers were covered with gauze and were large enough for the insects to carry on their normal activities. Following a definite period of exposure to a given temperature and pressure, the insects were removed to room temperature and examined about 5 minutes later. After this initial examination the insects were observed from 1 hour to 2 weeks before they were discarded. In some of the experiments the insects which were paralyzed were kept under observation at 25° C. for as long as two months.

A number of *Triatoma gerstaeckeri* were infected experimentally with *Trypanosoma cruzi* and 50 *Musca domestica* were infected with *Herpetomonas muscae domesticae*. For each test, 3 to 12 insects of each species were placed in separate containers in the chamber and were exposed to the temperature and pressure conditions which invariably caused their death. After the insects were removed from the chamber and it was ascertained that they were dead, they were dissected and intestinal material from each insect was examined microscopically for evidence of active haemoflagellates.

EXPERIMENTAL DATA[3].—The results of these studies are summarized in tables 1, 2, 3, 4, and 5. *Triatoma gerstaeckeri* exposed to temperatures of −5° C. and above, with corresponding negative pressures, remained viable and resumed their normal activities even after 48 hour exposure. At −10° C., after 2 hours exposure, the insects likewise suffered no apparent detrimental effects. However, when the time was extended from 2 to 24 hours, 4 out of 20 insects were killed, and the majority of the remainder developed permanent paralysis.

Triatoma gerstaeckeri exposed to −15° C. with corresponding negative pressure, for 15 minutes, remained viable. When this condition was extended to 30 minutes, it resulted in the death of 15 per cent and paralysis of 85 per cent of the insects. When the same condition was further extended to 1 hour, five out of six insects were found dead and one had a permanent paralysis. When the temperature was reduced to −15° C. with a negative pressure of 13 inches of mercury for

[3] In this study the terms "negative pressure" and "Partial vacuum" refer to experimental pressures below atmospheric pressure at Galveston, Texas. For example, a negative pressure of 13 inches of Hg is equal to an atmospheric pressure of 429 mm. or 16.9 inches of Hg.

Table 3.—The effects of temperature, pressure, and time on *Aedes aegypti*.

Conditions in the Chamber			Exposure Period		Mosquitoes Used	Effects on Mosquitoes		
						Number		
Temp. °C.	Negative Pressure Inches Hg.	Relative Humidity (per cent)	Hrs.	Min.		Dead	Survived	Paralysis Noted
0	7.4	90	12	0	5	0	5	–
0	7.4	90	34	0	11	0	11	–
−5	9.0	93	16	0	8	0	8	–
−5	9.0	90	24	0	10	4	6	–
−5	9.0	90	36	0	9	7	2	±
−5	9.0	90	48	0	11	8	3	±
−10	11.5	70	1	0	10	0	10	–
−10	11.5	70	4	0	9	0	9	±
−10	11.5	90	8	0	7	3	4	±
−10	11.5	90	12	0	14	14	0	–
−10	11.5	90	15	0	14	14	0	–
−15	13.0	90	2	0	13	13	0	–
−15	13.0	90	5	0	6	6	0	–
−15	13.0	83	8	0	8	8	0	–
−20	14.6	83	0	30	8	8	0	–
−20	14.6	60	1	0	13	13	0	–
−20	14.6	90	2	0	9	9	0	–
−20	14.6	90	4	0	8	8	0	–
−20	14.6	90	7	0	9	9	0	–
−25	16.2	80	0	15	9	0	9	–
−25	16.2	80	0	30	10	9	1	–
−25	16.2	80	1	0	8	8	0	–

30 minutes or less, the insects remained viable. When the length of exposure at this temperature was increased to 1 hour, it produced permanent paralysis of some insects. Exposures for 2 hours at this same temperature produced the death of two-thirds of the insects and permanent paralysis of one-third. When the time was increased at this temperature to 4 and 24 hours, all the insects died. A temperature of −20° C., with a negative pressure of 14.6 inches of mercury for 30 minutes, had no effect on *Triatoma*, while at 1 hour it produced a permanent paralysis of the insects.

Triatoma exposed to temperatures of −30° C. to −54° C., with corresponding negative pressures, were all killed within 15 minutes (Table 1). In some experiments, insects were kept at −15° C. from 1 to 2 hours without reduction of atmospheric pressure. Paralysis was produced in these insects. Other insects, kept at room temperature (+25° C.) in a partial vacuum for as long as 24 hours, did not manifest any signs of paralysis and resumed their normal activities when they were taken out of the containers.

Musca domestica were found to be more sensitive to cold and corresponding negative pressures than *Triatoma gerstaeckeri* (Table 2). These flies remained viable at −5° C. and corresponding negative pressure for 24 hours.

At a temperature of −10° C., with corresponding negative pressures, the flies were still viable at the end of 2 hours. However, when these exposure conditions were extended to 4 hours, 9 of the 10 insects were found dead, and one was paralyzed.

Aedes aegypti survived at −5° C. with a corresponding negative pressure for 16 hours; when the time was increased to 24 and 48 hours at this temperature and pressure, a number of mosquitoes were found dead, and some were partially paralyzed. A temperature of −10° C. with negative pressure of 11.5 inches of mercury for one hour had no detrimental effect on the mosquitoes; when the same conditions were extended to 4 and 8 hours, paralysis in a few of the mosquitoes was noted. Temperatures of −10° C. for 12 hours, −15° C. for 2 hours and −20° C. for 30 minutes with correspond-

Table 4.—The effects of temperature, pressure, and time on *Culex quinquefasciatus*.

Conditions in the Chamber			Exposure Period			Effects on Mosquitoes		
						Number		
Temp. °C.	Negative Pressure Inches Hg.	Relative Humidity (per cent)	Hrs.	Min.	Mosquitoes Used	Dead	Survived	Paralysis Noted
0	7.4	90	12	0	5	0	5	—
0	7.4	90	34	0	8	0	8	—
−5	9.0	93	16	0	10	0	10	—
−5	9.0	90	24	0	8	0	8	—
−5	9.0	90	36	0	8	2	6	+
−5	9.0	90	48	0	8	3	5	+
−10	11.5	70	1	0	7	0	7	—
−10	11.5	70	4	0	9	0	9	—
−10	11.5	90	8	0	10	0	10	—
−10	11.5	90	12	0	11	10	1	+
−10	11.5	90	15	0	6	6	0	—
−15	13.0	90	2	0	9	9	0	—
−15	13.0	90	5	0	7	7	0	—
−15	13.0	83	8	0	6	6	0	—
−20	14.6	83	0	30	8	0	8	—
−20	14.6	60	1	0	8	8	0	—
−20	14.6	90	2	0	7	7	0	—
−20	14.6	90	4	0	11	11	0	—
−20	14.6	90	7	0	10	10	0	—
−25	16.2	80	0	15	5	0	5	—
−25	16.2	80	0	30	5	5	0	—
−25	16.2	80	1	0	9	9	0	—

ing negative atmospheric pressures were all fatal to *Aedes aegypti* (Table 3.)

The effects of reduced temperature and pressure on *Culex quinquefasciatus* are illustrated in table 4. Careful examination of the data revealed that a temperature of −5° C. and above, with a corresponding negative pressure for 24 hours, had no ill effects on this mosquito. Exposure to − 5° C. from 36 to 48 hours had some detrimental effect. Mosquitoes survived in −10° C. atmospheric temperature for as long as 8 hours. When the time was extended to 15 hours at the same temperatures or −15° C. for 2 hours, −20° C. for 1 hour and −25° C. for 30 minutes with corresponding negative pressures, the results were found always to be fatal to *Culex quinquefasciatus*.

Bdellonyssus bacoti survived in the low pressure chamber at a temperature of −5° C. for as long as 16 hours. Exposure to a temperature of −10° C. with negative pressure of 11.5 inches of mercury for 8 hours resulted in no detrimental effect on mites. When this same temperature and pressure was extended to 12 hours, all the mites were killed. Exposure periods for 2 hours at −15° C. resulted in a fatality of 50 per cent. Temperatures of −15° C. for 5 hours and −20° C. for 1 hour with corresponding negative pressures always were fatal to tropical mites (Table 5).

The survival and death curves which plot the time against temperature are essentially similar for all species studied. In all these cases, a sharp inflection in the curve was noted between temperatures of −10° C. and −15° C.

The effects of low temperatures and reduced pressures on infectivity in two species of infected insects can be summarized as follows: Fifty *Musca domestica* experimentally infected with *Herpetomonas muscae domesticae*, when exposed to a temperature of −15° C. and a negative atmospheric pressure of 13 inches, died. Microscopic examination of the dead insects revealed the haemoflagellates still alive and active. *Triatoma gerstaeckeri* infected with *Trypanosoma cruzi*, and exposed to a temperature of −44° C. for 1 and 2 hours, with corresponding reduced

Table 5.—The effects of temperature, pressure, and time on *Bdellonyssus bacoti*.

Conditions in the Chamber			Exposure Period			Effects on Mites	
						Number	
Temp. °C.	Negative Pressure Inches Hg.	Relative Humidity (per cent)	Hrs.	Min.	Mites Used	Dead	Viable
0	7.4	90	12	0	9	0	9
0	7.4	90	48	0	13	0	13
−5	9.0	93	16	0	10	0	10
−5	9.0	90	24	0	10	6	4
−5	9.0	90	36	0	10	6	4
−5	9.0	90	48	0	10	5	5
−10	11.5	70	1	0	10	0	10
−10	11.5	70	4	0	10	0	10
−10	11.5	90	8	0	10	0	10
−10	11.5	90	12	0	10	10	0
−10	11.5	90	15	0	10	10	0
−15	13.0	90	2	0	10	5	5
−15	13.0	90	5	0	10	10	0
−15	13.0	83	8	0	10	10	0
−20	14.6	83	0	30	10	0	10
−20	14.6	60	1	0	10	10	0
−20	14.6	90	2	0	10	10	0
−20	14.6	90	4	0	10	10	0
−20	14.6	90	7	0	10	10	0

pressure, all died. The flagellates, however, remained alive and active within the dead insects (Table 1).

Discussion.—The experimental data on hand reveals that temperatures of −20° C. or below for about 2 hours are detrimental or lethal to most insects. At temperatures −5 to −15° C., with longer exposure periods, insects likewise were damaged or killed. Obviously there is an overlap between minimum and maximum of vital, survival, anabiotic and lethal temperatures. Multiple aspects of so many distinct factors on the one hand, and overlapping of ranges on the other, make it difficult to define the lethal low temperature for insects (Luyet & Gehenis 1940).

In the standardization and definition of thermal death point or lethal temperature usable for comparative studies and for determination of lethal cold coefficients of various insects, several important factors must be taken into consideration, i.e., the species of insect, its size, age, sex, temperatures in which it has been reared, the effect of the container in which the insects are subjected to a given temperature, time of action of low temperature, rate of cooling and warming, state and condition of insects before and during cooling, acclimatization of insects to both of these temperatures, etc. Efforts will be made to standardize and define the lethal temperatures of a suitable insect with due consideration to all above factors.

The experimental results of this study revealed also that the paralysis produced in *Triatoma gerstaeckeri* at certain low temperatures and given periods of time was independent of negative atmospheric pressure. The exact mechanism responsible for producing the permanent paralysis of *T. gerstaeckeri* has not yet been determined. The effect of rapid subfreezing to the vitrifying or sublimation temperature in such a manner that possible ice formation in the tissues of the insect can be prevented, represents an important problem for further study.

Revival of insects after they were cooled at a certain temperature for given periods and removed to room temperature was not always immediate. In certain experiments, several hours or even days elapsed at room temperature before the insects were able to resume their normal activities. In some instances it was difficult to ascertain whether seemingly dead insects were really dead or in the "hibernating stage."

The newly-developed equipment with

the low pressure chamber, or "stratosphere chamber" used in the present study because of its various adjustable features, compactness and ease of operation, will facilitate studies not only of the problems pertaining to the standard atmosphere but also the stratosphere. It will likewise be useful for simulating conditions on the surface of submarines where increased atmospheric pressure is one of the main factors.

SUMMARY AND CONCLUSIONS.—A new apparatus, a Low Temperature Refrigerator with Low Pressure Chamber, has been constructed that can be used conveniently for studying the effects of low temperatures and atmospheric pressures on small mammals, insects, and microorganisms and for simulating the low temperature and negative pressure conditions existing at various altitudes. The working space of the chamber measures 12×12×12 inches. Within this chamber any desired temperature ranging from +25° C. to as low as −85° C. can be maintained. Atmospheric pressures as high as 1320 mm. of mercury to as low as 10 mm. of mercury can be held indefinitely, concurrently with or independently of the temperature within the chamber.

Five species of arthropods, i.e., *Aedes aegypti*, *Bdellonyssus bacoti*, *Culex quinquefasciatus*, *Musca domestica*, and *Triatoma gerstaeckeri* were exposed for different periods of time to the low temperature and negative pressure conditions corresponding to various altitudes. All of the arthropods studied were killed within 4 hours at a temperature of −15 ° C. with an atmospheric pressure of 429 mm. of mercury (conditions corresponding to an altitude of 15,000 feet above sea level). All of the insects exposed to a temperature of −5° C. with an atmospheric pressure of 522 mm. of mercury (conditions corresponding to an altitude of 10,000 feet above sea level) survived and resumed their normal activities. The survival and death curves which plot the time against temperature are essentially similar for all species studied. In all cases a sharp inflection in the curve was noted between temperatures of −10° C. and −15° C.

The low temperature and low pressure conditions which were just below the lethal level produced permanent paralysis of some of the insects exposed, notably of *Triatoma gerstaeckeri*. These paralyzed insects were unable to feed on experimental animals or transmit diseases to them.

Twenty-four *Triatoma gerstaeckeri* which were exposed at +25° C. with a negative pressure of 20 inches of mercury for 24 hours, were uninjured and resumed their normal activities at the end of the experiment. A few *Triatoma*, exposed to a temperature of −15 °C. with normal atmospheric pressure (no vacuum) for 1 to 2 hours were all permanently paralyzed.

Musca domestica, infected with *Herpetomonas muscae domesticae*, exposed to a temperature of −15° C. for 2 hours, and *Triatoma gerstaeckeri*, infected with *Trypanosoma cruzi*, exposed to a temperature of −44° C. for 2 hours (both with corresponding reduced pressure), all died; the flagellates, however, remained alive and active within the dead insects.

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Resistance to DDT by the Grape Leafhopper *Erythroneura variabilis* Beamer[1]

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The grape leafhopper *Erythroneura variabilis* Beamer, a major pest of grapes, is the only leafhopper species that has been encountered in high populations in southern California vineyards. This species also occurs as a vineyard pest in Arizona, along with *Dikrella cockerellii* (Gillette). The latter species occurs on native wild grapevines in southern California, as does *E. elegantula* Osborn, the grape leafhopper of the San Joaquin Valley.

One of the earliest demonstrations of the potentialities of DDT in vineyard leafhopper control took place in 1944, when this insecticide was applied as a dust on the Tal-wi-wi ranch near Phoenix, Arizona. DDT was used in subsequent seasons on this property, generally in thermal aerosol applications or as a dust. In 1950, difficulties were experienced in obtaining adequate control, and by 1952 the use of DDT had been discontinued because of control failure. The Arizona *Erythronura variabilis* employed in the present studies was collected from this vineyard.[4]

In southern California, well-timed treatments with DDT, well applied either by dusting or by spraying, provided excellent control during the first few years of its use. Typical results of experimental applications of DDT in 1947 (Barnes 1947)[5] are shown in table 1. Although concentrated spray applications provided control with smaller amounts of DDT per acre than dust applications, growers have preferred the latter, since sulfur dust may be effectively applied simultaneously for control of powdery mildew.

Table 1.—Control of grape leafhopper in the field by application of DDT dusts and sprays, 1947.[1]

	Treatment		
Application Method	Formulation	Pounds Technical DDT per Acre	Per Cent Control After 7 Days
Field power duster[2]	5% DDT dust	1.2	99
Field power duster[2]	5% DDT dust	0.7	91
Vapor sprayer	2% DDT in light petroleum fraction	0.5	96
Airplane sprayer	25% DDT in xylene in 10 gals. water	0.5	99

[1] Barnes (1947).
[2] Manufactured by the Master Fan Corporation.

In 1951, following reports of poor control with DDT dusts in the Coachella Valley of southern California, a 5-acre vineyard in that area was sprayed in late August with a boom sprayer, using 4 pounds of a 50 per cent DDT wettable powder in 200 gallons of water per acre. The dosage and gallonage employed were in keeping with the purpose of the application, which was to determine whether

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[2] Assistant Entomologist in the Experiment Station.
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[4] Identification of this leafhopper and of the California *Erythroneura variabilis* was confirmed by Dr. R. H. Beamer of the University of Kansas.
[5] Unpublished data on file at the University of California Citrus Experiment Station, Riverside, Calif.

the leafhopper could be controlled with a reasonable dosage of DDT applied in a manner that would insure good coverage and initial deposit. Excellent control resulted in this vineyard. Although it was possible that resistance might exist to a degree influencing results afforded by the lighter and more transient deposits from dust applications, leafhoppers in this case were still sufficiently susceptible for successful employment of DDT.

Reports of difficulty in controlling grape leafhoppers with DDT in the Coachella Valley continued during 1952. Results of experimental applications indicated, however, that a 10 per cent DDT dust applied at 20 pounds per acre—twice the amount of DDT usually employed in dust applications—would provide very good control. Grower applications of DDT in concentrated sprays both by ground equipment and by airplane also resulted in good control.

In November, 1951, a population of *Erythroneura variabilis* was obtained from the Arizona location previously described. These leafhoppers, which were collected from their overwintering quarters in a grapefruit orchard, were caged on lemon foliage which had been dipped in an acetone solution of DDT. The resulting mortality was considerably less than expected. These results together with the field experience indicated the desirability of additional studies.

The best way to determine whether a species can develop resistance to an insecticide is to rear the species under continuous exposure to the insecticide and then compare with unexposed stock. If this is not possible, comparisons of field-collected strains having varied histories of insecticide exposure provide valuable information. When initial use of an insecticide affords very good control of a species in all areas, as in the case of DDT for *Erythroneura variabilis*, it may be assumed that all wild, unexposed populations are relatively susceptible. An isolated vineyard near Verdemont, California, which was abandoned before DDT became available, was selected as the source of a population of *E. variabilis* unexposed to DDT, hereafter referred to as the Verdemont population.

PRELIMINARY GREENHOUSE TRIAL.—For this trial, populations of *Erythroneura variabilis* were collected in Arizona in August, 1952, and caged on bench-grown Zinfandel vines for 4 days before being used. These leafhoppers were compared with those of the California Verdemont population, as follows. Five of ten potted vines were sprayed on a turntable with 2 pounds of a micronized wettable powder containing 50 per cent technical DDT and 50 per cent diluent,[6] with no wetting agent, per 100 gallons; the five remaining vines were untreated. One hundred leafhoppers of each of the two populations were separately confined in cloth sleeve cages on each of the ten vines. After 24, 48, and 72 hours of continuous exposure, mortality counts were made by shaking the dead leafhoppers into the distal end of each sleeve cage, which was closed with a transparent disc. The results of this preliminary trial, presented in figure 1, show considerable difference in susceptibility of the two populations of leafhoppers to DDT.

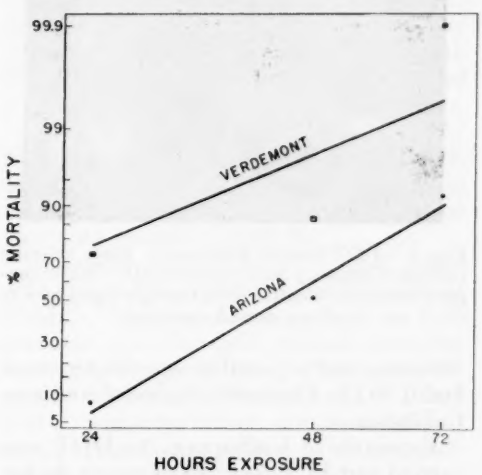

FIG. 1.—Per cent mortality (probit scale) of leafhoppers from a previously untreated vineyard (Verdemont), at 1, 2, and 3 days (log. scale), as compared with that of leafhoppers from a treated vineyard (Arizona), when confined on DDT-sprayed grape foliage. Data corrected for check mortality by Abbott's formula.

LABORATORY TRIALS.—To obtain further information on the existence of differences in susceptibility of field-collected populations of *Erythroneura variabilis* to DDT, exposure-time—mortality data were obtained from three populations of leafhoppers, namely, the Verdemont, the

[6] *Attaclay*; Attapulgus Clay Corporation, Philadelphia, Pa.

FIG. 2.—DDT-treated Erlenmeyer flask, showing method of exposing leafhoppers to DDT. Water supplied by means of cotton wick through tygon tube to reduce natural mortality.

Arizona, and a population collected near Indio, in the Coachella Valley of southern California.

Exposure of leafhoppers to DDT was carried out in 125-cc. Erlenmeyer flasks. Recrystallized *p,p'*-DDT was dissolved in acetone at 0.2 per cent, and 0.72 cc. of this solution was pipetted into each flask. This amount of DDT provides a deposit of about 10 mg. per square foot on the inner surface of the flask. The flask was slowly rotated so that the solution was evenly spread on all inside surfaces except the neck. While there was still an even film of acetone on the surface, a tube leading to a vacuum line was introduced into the flask. This quickly removed the remaining acetone, leaving the inside of the flask coated with well-dispersed droplets of super-cooled DDT. These droplets, if undisturbed, will remain uncrystallized for long periods. The droplets crystallize instantly when touched by the tarsi of the leafhoppers as they crawl about after introduction into the flask.

Natural mortality of leafhoppers was effectively reduced by providing them with water by means of a dental roll of absorbent cotton inserted through a tygon tube wrapped in the cellulose cotton flask stopper (Fig. 2). Additional water may be supplied to the wick as required by dropping it into the tube. Natural mortality in the check flasks never exceeded 10 per cent. In fact, when water, only, is supplied, leafhoppers can be held for at least 1 week, and possibly longer, with very low mortality.

Fifty leafhoppers were used for each exposure, and each treated flask was used for one exposure only. During exposure the flasks were under light continuously. After the desired exposure period, the leafhoppers were transferred to untreated flasks and held 24 hours before mortality counts were made. This transfer was carried out while the leafhoppers were anesthetized with CO_2. Flasks were held in a shaded area in a greenhouse section maintained at approximately 80° F.

Results of exposures of the three populations of leafhoppers to DDT for varying periods, and in the manner described, are presented in figure 3. The expected straight-line relationship exists between the log of the exposure time and percentage mortality when the latter is plotted on a probit scale. Each point in figure 3 represents the average mortality of three replicates of 50 leafhoppers each, cor-

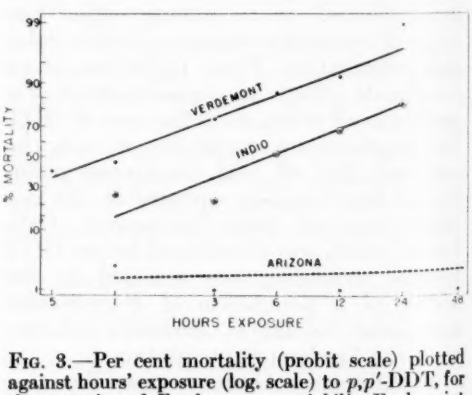

FIG. 3.—Per cent mortality (probit scale) plotted against hours' exposure (log. scale) to *p,p'*-DDT, for three strains of *Erythroneura variabilis*. Each point represents an average from three replications of 50 leafhoppers each.

rected by Abbott's formula (Abbott 1925) for mortality in two untreated flasks for each point. Leafhoppers in the untreated flasks were handled, anesthetized, etc., in the same manner as those in the treated flasks.

The resulting mortality curves (Fig. 3) show that the three populations of leafhoppers represent three strains varying in their susceptibility to DDT in the order expected. The Arizona strain proved very resistant under these conditions, 48-hour exposure periods failing to produce significant mortality. Leafhoppers of this strain were also held in treated flasks for as long as five days without significant mortality.

Leafhoppers of the Indio strain were more susceptible than those of the Arizona strain, but less susceptible than those of the Verdemont strain. The data for the Verdemont and Indio strains were analyzed by linear regression methods. The lines are parallel and are significantly different. The odds are greater than 19:1.

TRIALS WITH DDT ACTIVATORS.—Many compounds have been shown to increase the toxicity of DDT to DDT-resistant strains of the house fly (March *et al.* 1952, Speroni 1952). Four of these compounds were tested for possible activation of DDT against the most resistant (Arizona) strain of leafhoppers. These trials were conducted in Erlenmeyer flasks, as previously described. Results are presented in table 2.

Bis(*p*-chlorophenyl) chloromethane,[7] though practically nontoxic to house flies, proved to be highly toxic to both resistant and nonresistant leafhoppers. The fine droplets of this compound remaining on the walls of the flasks after evaporation of the acetone failed to crystallize when leafhoppers were introduced. Since the wings of leafhoppers became entangled by the sticky droplets, a reduction in the deposit was necessary. The use of 0.72 cc. of a 0.03 per cent solution of this compound per flask produced a deposit one-seventh of that commonly employed with DDT. With this, leafhopper mortality was complete after a 24-hour exposure plus the usual 24-hour holding period. The leafhoppers were more or less continuously exposed to tiny droplets of the liquid compound as they walked about in the flask. Such exposure would presumably be more effective than exposure to the crystallized compound. To demonstrate true activation of DDT, a compound relatively nontoxic to leafhoppers should be used; hence further trials with this compound for the purpose at hand were not conducted.

Table 2.—Results of laboratory trials with DDT activators on grape leafhopper.

COMPOUND	PER CENT IN ACETONE[1]	PER CENT MORTALITY[2]	LEAFHOPPER STRAIN
DDT	0.20	5	Arizona
Bis(*p*-chlorophenyl) ethynyl carbinol	0.03	29	Arizona
DDT Bis(*p*-chlorophenyl) ethynyl carbinol	0.20 0.03	24	Arizona
Bis(*p*-chlorophenyl) chloromethane	0.03 0.05	100 100	Verdemont Arizona
DDT Bis(*p*-chlorophenyl) methyl carbinol	0.4 0.06	5	Arizona
p,p'-Dichlorobenzenesulfonanilide	0.2	0	Verdemont
DDT *p,p'*-Dichlorobenzenesulfonanilide	0.2 0.2	4	Arizona

[1] At the rate of 0.72 cc. per 125-cc. Erlenmeyer flask.
[2] Exposure time 24 hours. Corrected by Abbott's formula for mortality in the check.

Bis(*p*-chlorophenyl) ethynyl carbinol,[7] proved to be slightly toxic to leafhoppers, but when incorporated with DDT in flask trials, no significant difference in mortality resulted (Table 2).

Sufficient crystallization took place with bis(*p*-chlorophenyl) methylcarbinol (DMC),[8] that solutions as high as 0.06 per cent could be used without resulting in entanglement of the leafhoppers. Exposure to combined deposits of DDT and DMC deposited from acetone did not result in significant mortality of the resistant strain of leafhoppers (Table 2).

Deposits of *p,p'*-dichlorobenzenesulfonanilide,[9] from acetone solution crystallized very well upon introduction of leafhoppers into the flask and were nontoxic to leafhoppers, but when incorporated with DDT, as described in table 2, failed to produce mortality of resistant leafhoppers.

The incorporation of these materials with DDT in the deposits necessarily alters the DDT deposit, and the resulting exposure to DDT is changed. These

[7] Rohm and Haas Company.
[8] Sherwin-Williams Company.
[9] The Dow Chemical Company.

trials do not show that these compounds cannot activate DDT; they show only that activation did not occur during the 24-hour exposures in these trials.

SUMMARY.—During the first 4 or 5 years of its use in vineyards for control of the grape leafhopper *Erythroneura variabilis* Beamer, DDT provided very satisfactory control in all localities. Following field reports of difficulty in control, a preliminary greenhouse trial with two populations of this leafhopper, one from a previously untreated vineyard (Verdemont) and the other from a heavily treated vineyard (Arizona), showed a marked difference in the susceptibility of the two populations to DDT. These results led to further investigations in the laboratory. A third population from a vineyard (Indio) having a history of DDT usage and performance intermediate between that of the first two was included in these trials.

Deposits of *p,p'*-DDT from a solution of 0.2 per cent DDT in acetone in 125-cc. Erlenmeyer flasks were used in the laboratory trials, and exposure-time—mortality curves were constructed for the three leafhopper populations. Results show that these populations represent three strains which vary in susceptibility to DDT. The Verdemont strain was the most susceptible of the three to DDT. The Indio strain was significantly less susceptible to DDT than the Verdemont strain (>19:1). The Arizona strain proved to be very resistant to DDT, 48-hour exposure to DDT providing no mortality.

Three compounds, bis(*p*-chlorophenyl) methylcarbinol (DMC), bis(*p*-chlorophenyl) ethynyl carbinol, and *p,p'*-dichlorobenzenesulfonanilide, which have been shown to activate DDT against resistant house flies, failed to activate DDT against the resistant Arizona strain of leafhoppers. A fourth compound, bis(*p*-chlorophenyl) chloromethane, proved to be too toxic to the leafhoppers for use in a DDT activation study.

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The Periodical Cicada in Maryland in 1953[1]

CASTILLO GRAHAM and A. BOYD COCHRAN[2,3]

Brood X of the periodical cicada, *Magicicada septendecim* (L.), reappeared in 1953. In Western Maryland, the population was exceedingly heavy in woodland and in apple orchards where trees existed 17 years ago.

DAMAGE.—Most of the young plantings of apple trees in this area were placed between old trees. In most cases, the old trees were removed during the past 2 or 3 years. A section of one orchard was removed in 1946, and the ground lay fallow until 1948 at which time it was reset. In the interim, the stumps were removed and the ground subsoiled. This section of the orchard was adjacent to a block where the young trees had been set between the old ones which were removed in 1952. The cicada population in the former block was negligible and no appreciable damage occurred to the young trees. In the adjacent block, the population was extremelyheavy and the young trees were severely damaged even though they were treated with

[1] Scientific Article A440. Contribution Number 2497, Department of Entomology, University of Maryland.

[2] Field Entomologist and Assistant in Entomology, respectively, Department of Entomology and Horticulture Field Station, Hancock, Maryland.

[3] Samuel R. Dillon, Jr., John Day and Jesse Clingerman of the Dillon Orchards, rendered valuable assistance in collecting data and making field observations.

five applications of tetraethyl pyrophosphate. Both blocks of old trees had similar infestations in 1936. It therefore appears that the cicada nymphs in the block where the trees were removed in 1946 perished before reaching maturity.

The damage to bearing apple trees varied according to the population of cicadas. In orchards where severe populations occurred, the periphery of the tree turned black with dead twigs. There is no way of making an accurate evaluation of the damage incurred by the cicada to the current or future crops. It is evident that some fruit is lost by the breakage of limbs during the activity of the brood. It is further evident that fruit on severely damaged limbs is reduced in size. However, it is the opinion of the authors, and some growers, that damage incurred from the above causes is less than 5 per cent of the crop. The loss of apples from the breakage of limbs near the time of harvest was negligible in this area.

BIONOMICS.—*Emergence.*—In order to get accurate data on the length of the emergence period, a wire mesh cage covering 7 square feet was placed under a tree where the burrows indicated a heavy population. Emergence began on May 19 and continued until June 3. A total of 137 adults emerged under the cage. In another orchard, a few miles distant, emergence started on May 14. Mating was observed on May 21 and oviposition started on May 24. The eggs began to hatch about July 25 with the peak occurring before August 5. Records were kept on the number of males and females emerging from under the cage and by daily examination of adults collected at random in the orchard from May 18 until July 2 at which time adults were hard to find. The proportion of sexes taken from the cage and found in orchards are shown in table 1.

In an attempt to get records on the length of the hatching period and the number of nymphs emerging from an estimated area, the limbs from a heavily infested apple tree, 6 feet in diameter and 7 feet tall, were cut in 2-foot lengths and placed on a wide-mesh screen-top table with cloth suspended below to catch the nymphs. Daily observation showed that as the limbs became dehydrated, the eggs began to shrivel. It later became obvious that no hatching would occur in the dead limbs. Observations in several orchards showed that no eggs hatched in twigs that died regardless of whether they remained on the trees or dropped to the ground.

Table 1.—The proportion of sexes of periodical cicadas collected in the field, and under a cage.[1] (Shown in 5 day periods.)

Date Examined	Number Examined	Per Cent	
		Males	Females
May 18	200	76.0	24.0
May 19–23	1300 (50)	61.4 (86.0)	38.5 (14.0)
May 24–28	900 (103)	48.0 (46.6)	52.0 (53.4)
May 29–June 2	800 (16)	35.8 (6.2)	64.2 (93.8)
June 3– 7	800 (3)	13.8 (0)	86.2 (100)
June 8–12	750	31.6	68.4
June 13–17	500	27.8	72.2
June 18–22	450	23.9	76.1
June 23–27	225	27.0	73.0
June 28–July 2	100	16.0	84.0

[1] Collections from the cage which ended on June 3 are shown in parenthesis.

Twenty-five unfertilized females were placed in a wire mesh cage, which was placed around apple limbs and secured at both ends with cloth to prevent the cicadas from escaping. Twenty-five males and 25 females were treated similarly in another cage. After all of the cicadas in both cages had died, the limbs were removed and examined for eggs and egg punctures. Oviposition was about equal in each cage. The removed limbs were placed in battery jars and observations made to determine if hatching occurred. No hatching occurred in either jar.

CONTROL.—*Soil Treatment.*—Several insecticides were tested as ground sprays against the nymphs. These sprays were applied a few days before emergence started, using a portable rig and applying approximately 30 gallons to the soil under each tree. Examination of the soil where each treatment was applied and observations on emergence indicated that all treatments were ineffective. Several acres of orchard where the turrets averaged approximately 30 per square foot were disked about a week before emergence started. All of the turrets were destroyed to a depth of 6 inches. Within a few days the turrets were reconstructed and observations indicated that disking was of no value in reducing the population. The insecticides and the amounts used in 100 gallons of spray were: chlordane (40 per cent) 2 lbs., chlordane (40 per cent) 4 lbs., BHC (10 per cent

gamma isomer) 2 lbs., BHC (10 per cent gamma isomer) 4 lbs., dieldrin (15 per cent emulsion) 1 qt., dieldrin (15 per cent emulsion) 2 qts., parathion (47 per cent emulsion) 2 qts., tetraethyl pyrophosphate (40 per cent) 1 qt., tetraethyl pyrophosphate (20 per cent) 1 qt.

Spraying caged adults.—Newly emerged adults were placed in screen wire cages, 8 inches in diameter and 16 inches long, and hung in trees before spraying. The sprays were applied with an air blast machine, delivering 42,800 cubic feet of air per minute at a velocity of 90 miles per hour. Trees were sprayed from both sides with the machine traveling 2 miles per hour. Results from these tests were not consistent. In another set of tests, using the same insecticides, heavily infested trees were sprayed and the wetted specimens were collected and placed in cages and hung in the tree. Daily observations were made to determine the mortality in each cage. Untreated cages were placed in trees out of reach of the drift, for comparison. The insecticides used in these tests were: dieldrin (15 per cent emulsion) 1½ qts.; BHC (10 per cent gamma isomer) 3 lbs.; parathion (15 per cent) 2 lbs.; parathion (47 per cent emulsion) 1½ pts.; CS-708 (25 per cent emulsion) 1 qt.; malathion (25 per cent) 5 lbs.; TDE (25 per cent emulsion) 2 qts.; methoxychlor (50 per cent) 3 lbs.; TEPP (40 per cent)[4] 4 to 8 ounces; TEPP (20 per cent)[4] 4 to 10 ounces, metacide[5] 1½ pts.; EPN 300 (24 per cent W.P.)[6] 2 lbs. TEPP was the only material used in these tests that gave satisfactory kill of the adult cicadas. Six to 8 ounces of the 40 per cent and 8 to 10 ounces of the 20 per cent material to each 100 gallons of spray were required to give approximately 100 per cent kill. The stronger dosage gave 100 per cent kill in about 6 hours whereas the weaker strengths required several hours longer.

In commercial orchards.—Observations made in several commercial orchards where TEPP was used at recommended strengths, showed good initial kill in most cases. Up to five applications were used in some young orchards where the population was extremely heavy, and even though good control was obtained with each application, serious damage occurred. Similar results occurred in old orchards where from 1 to 3 applications were applied. Growers reported various degrees of control, some indicating excellent control, others questioned the value of the applications. The only method of treatment that proved entirely satisfactory was wrapping the young trees with cheese cloth.

CONCLUSIONS.—The periodical cicada, *Magicicada septendecim* (L.), caused severe damage to young trees in all orchards where the population was heavy and where the trees were not protected by cheese cloth. Limbs of old trees were severely damaged, but the loss of fruit as the result of this injury was believed to be less than 5 per cent of the crop. No loss of fruit resulted from the breakage of limbs immediately before or during harvest. Observations on cicadas in orchards showed that the first emergence occurred on May 14. During the first week of emergence there were more males than females; thereafter the reverse was true until observations were discontinued on July 2. Oviposition was observed on May 24. The peak of hatching occurred between July 25 and August 25. Eggs did not hatch in dead and dried limbs whether they stayed on the tree or dropped to the ground. Unfertilized females deposited eggs when caged on limbs. Disking of orchards, or spraying the ground with insecticides a few days before emergence started, failed to give control. Of the various insecticides used against the adult, TEPP was the only one that gave a high kill.

[4] Furnished by the California Spray-Chemical Corporation.
[5] Furnished by Pittsburgh Agricultural Chemical Co.
[6] Supplied by E. I. du Pont de Nemours & Company, Inc.

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Fly Production Sources in Urban Communities

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Knowledge concerning the relative importance of various substrates in producing fly populations in urban areas is of vital consequence to those engaged in fly control activities. Moreover, in recent years the widespread occurrence of house fly resistance to chlorinated hydrocarbon insecticides has accentuated the need for pertinent information on fly breeding habits as a foundation for the increased reliance upon environmental sanitation as the principal weapon of control. To investigate this ecological problem, surveys of fly breeding sources were conducted in Charleston, West Virginia (1951 and 1952), Phoenix, Arizona (1951 and 1952), and Topeka, Kansas (1950).[1] This paper describes the findings obtained at Charleston, West Virginia, with limited mention of the data from Topeka, Kansas. The results from Phoenix, Arizona, were reported previously by Siverly and Schoof.[2]

Description of Study Areas.—The study area listed as Charleston, West Virginia, was composed of two contiguous communities, Charleston and South Charleston (total population, 90,187). Both cities represented heavily industrialized municipalities located on the banks of the Kanawha River. A total of 1600 blocks was present in the two communities, these blocks representing diversified levels of sanitation which ranged from substandard conditions to those characteristic of maximum cleanliness.

Since the Charleston area was subject to fly control measures, limited surveys were also conducted in the nearby untreated towns of Dunbar and St. Albans, West Virginia. Both cities were in the 8,000 population class and possessed a physical make-up similar to Charleston, with the exception that animal pens were encountered more frequently in the untreated communities.

Survey Procedures.—For the purpose of this study, the sampling pattern was superimposed upon the design utilized in conducting the routine appraisal of adult fly densities in the community. All blocks within the city were grouped into socioeconomic sections which in turn were divided into homogeneous units of 10 to 20 blocks each. Within each unit, the block of highest fly productivity was designated as a survey station. A rotation schedule was followed whereby representative blocks of each socioeconomic category were surveyed on a weekly rate, a 50 per cent coverage of the total number of units in the municipality being achieved during each 4-week period. In general, an average of 56 blocks was covered monthly, the same stations being checked routinely throughout the season.

To insure adequate coverage of all types of socioeconomic conditions, the survey blocks were classified in accordance with the following categories:

Type I (High class residential).—Residential blocks with excellent premises sanitation, weekly refuse collection, animal shelters absent except for occasional dog houses.

Type II (Middle class residential).—Blocks with good premises sanitation, weekly refuse collection, occasional rabbit or chicken pens, or business establishments.

Type III (Low class residential).—Blocks with poor premises sanitation, inadequate refuse collection, numerous animal pens.

Type IV (Dump blocks).—Blocks characterized by exceptionally high fly potential. For example, refuse dumps, commercial enterprises, etc.

Type V (Business).—Blocks containing over 50 per cent business establishments, daily garbage collection.

In the survey of a block, the inspector made a diligent search for fly breeding substrates of all types. Samples of positive substrates were collected and returned to the field station for rearing purposes in 1951 or for larval identification in 1952. During 1952, the specimens were reared only when the sample contained larvae which were not readily identifiable by the available keys.

Results.—The relative importance of different substances based on the frequency of occurrence of positive samples is depicted in figures 1 and 2.[3] During both years, garbage represented approxi-

[1] The Topeka surveys were preliminary studies of limited coverage.

[2] Siverly, R. E., and H. F. Schoof. (Unpublished manuscript.) Utilization of various production media by muscoid flies in a metropolitan area. I. Adaptability of different flies for infestation of prevalent media. II. Seasonal influence on degree and extent of fly production. III. Fly production in relation to city block environment. Communicable Disease Center, Phoenix, Arizona, and Atlanta, Georgia.

[3] Part of the cost of reproducing the figures accompanying this paper is being paid by the Public Health Service.

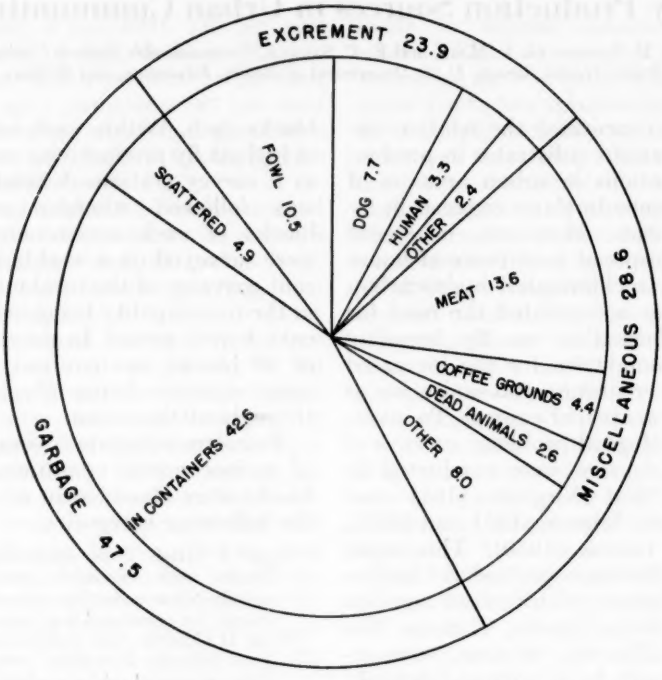

FIG. 1.—Relative percentage of the various types of fly infested media. (389 samples.) Charleston, West Virginia—1951.

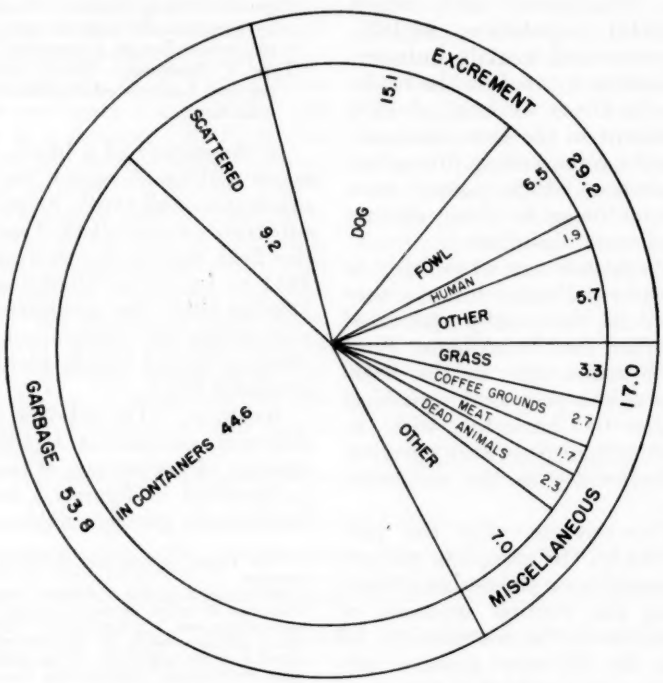

FIG. 2.—Relative percentage of the various types of fly infested media. (665 samples.) Charleston, West Virginia—1952.

mately one-half of all positive samples detected. Although numerous media such as fowl excrement, dog stools, sea food wastes, and dead animals yielded a higher percentage of positive samples in relation to the total number of the particular substrate located, the ubiquitous occurrence of garbage in the city overshadowed these as to over-all significance in fly production.

Dog stools and fowl droppings composed over two-thirds of the total positive excrement samples detected. Because of zoning restrictions, feces of the larger domestic animals were almost wholly absent. In the miscellaneous categories, meat, dead animals, and coffee grounds predominated.

These data for Charleston, West Virginia, agree with those from surveys in Topeka, Kansas (Figure 3). and Phoenix, Arizona (Figure 4), garbage also being the most frequent positive substrate encountered at these cities. However, excrement at both Topeka, Kansas, and Phoenix, Arizona, achieved greater relative significance than at Charleston, West Virginia, a shift which probably reflects the increase in tolerance for animals which occurs in the western parts of the United States. At Topeka, cow dung represented 14.8 per cent of the total positive substrates, and at Phoenix, cow-horse excrements accounted for 14.6 per cent. Positive samples of such fecal matter were encountered only four times at Charleston.

In table 1, the data depict the relative importance of the different substrates in the residential and business areas. In the residential blocks, the fewest number of substrates (except excrement) and the lowest percentage of positive substrates were detected in the zone with the highest socioeconomic level. In the garbage category, the amount and the infestation rate increased with the decline in premises sanitation but in the excrement and miscellaneous categories, the increase followed an irregular sequence. The business zone exhibited the highest infestation rate in garbage but contained fewer substrates than all but the high-class residential blocks. Presumably the latter reflected the effect of the daily garbage pick-up in the business area. On a comparative basis, garbage produced the highest number of substrates per block inspection in all four socioeconomic categories.

Table 2 summarizes the species composition of the larvae which infested the different substrates. As the data show, the principal species recovered from samples of contained garbage were the blow flies *Phaenicia sericata* and *Phaenicia pallescens*, and the house fly, *Musca domestica*. Discounting double infestations which occurred in the same samples, the blow fly group predominated in refuse stored in containers. Although *M. domestica* was found in 27.9 per cent of the positive garbage can samples, refuse under these conditions was much less readily infested with this species than when it was scattered on the terrain. The reverse was true with the blow fly species.

Dog stools were the most common excrement detected during the survey period. In this medium, *Sarcophaga* spp. predominated, maintaining a percentage infestation rate of 96 per cent for both survey years. *Sarcophaga* spp. also were the chief species produced from human feces (64.7 per cent) with house flies, *Ophyra* spp. and *Phaenicia sericata* also being detected therein. Fowl excrement served as a source of a host of species, of which *Musca domestica* was predominant.

The infestation rates for the various species in the miscellaneous substrates indicated that meat scraps was the substrate most frequently encountered during the survey. This medium yielded 12 dif-

Table 1.—Average number substrates per block and percentage of substrates positive in residential and business areas. Charleston, West Virginia, 1951 and 1952.

Media	Residential Class			Business District
	High	Middle	Low	
Garbage				
Av. no. substrates per block	2.2	3.9	5.7	3.8
Per cent samples positive	9.5	13.4	16.9	17.9
Excrement				
Av. no. substrates per block	0.9	1.2	0.7	0.4
Per cent samples positive	22.5	33.3	30.3	21.4
Miscellaneous				
Av. no. substrates per block	0.5	0.7	1.2	0.9
Per cent samples positive	14.3	29.7	25.3	23.8

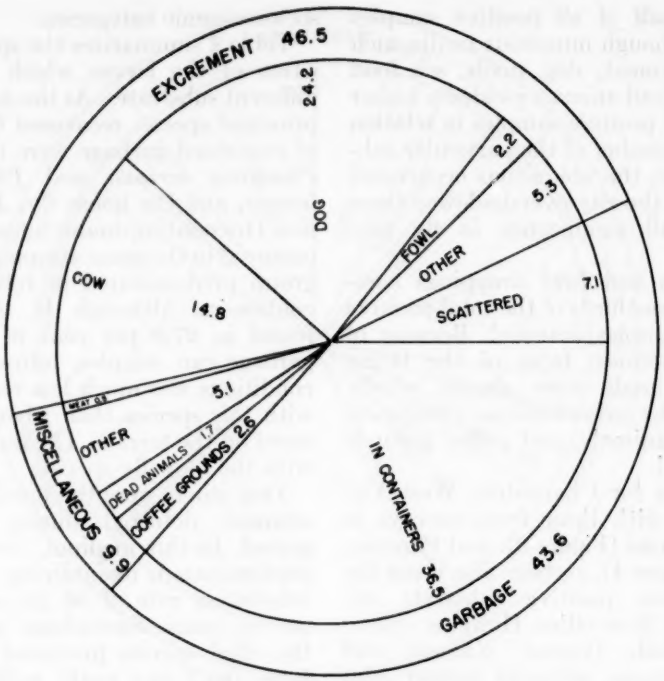

FIG. 3.—Relative percentage of the various types of fly infested media. (636 samples.) Topeka, Kansas—1950.

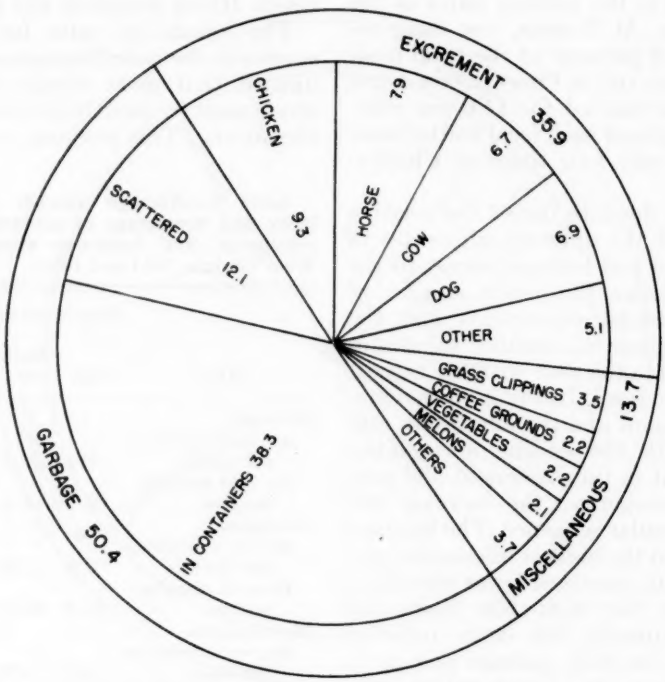

FIG. 4.—Relative percentage of the various types of fly infested media. (807 samples.) Phoenix, Arizona—1951 and 1952.

Table 2.—Frequency of occurrence of different fly larvae in various breeding media (769 samples), Charleston, West Virginia, 1951–52.

SPECIES	EXCREMENT						GARBAGE		MISCELLANEOUS MEDIA					TOTAL POSITIVE SAMPLES PER SPP.
	Cow	Horse	Human	Fowl	Dog	Other	Scattered	In Container	Grass Clippings	Coffee Grounds	Dead Animals	Meat	Sea Food Wastes	
Musca domestica		1	3	27	4	13	46	105	1	13	1	1		215
Phaenicia sericata		1	2	2			8	119		7	5	16	3	163
Phaenicia pallescens				2			9	113		2	1	13	1	141
Phaenicia caeruleiviridis				1				8			4		1	14
Sarcophaga spp.			11	1	74		5	51		3	4	12	3	164
Phormia regina				1			2	40		1	4	14	3	65
Muscina spp.	3			3	1	12	7	50	5	1		4		86
Calliphora spp.				3			5	13	3	3	4	4	1	36
Stomoxys calcitrans				4		4	2	3	10				1	24
Callitroga macellaria								11			3	1		15
Ophyra spp.			1	8		3	3	9		1	2	2	2	31
Cynomyopsis cadaverina							1	2			3	1		7
Lucilia illustris								1			1			2
Others				3	3	5	5	12		4		2	1	32
Total positive samples per type medium	3	1	17	44	77	33	76	377	19	34	25	51	12	

ferent species, with *Phaenicia sericata*, *Phaenicia pallescens*, *Phormia regina*, and *Sarcophaga* spp. being represented in more than 23 per cent of the positive samples collected. Of interest is the paucity of *Callitroga macellaria* in infestations of meat scraps. A similar absence of *C. macellaria* in meat samples was reported at Phoenix, Arizona (Siverly and Schoof).[2]

DISCUSSION.—Results of the Charleston survey indicate two types of fly producing sources in the area: (a) localized sites of high fly productivity (e.g., poultry plant); (b) numerous scattered areas of relatively low productivity (e.g., garbage cans, animal pens, etc.). The poultry concern listed under (a) provided an ample, continuous supply of fowl excrement. In 1951, 61 per cent of the 49 samples at this site were positive; in 1953, the percentage rose to 83. In contrast, fowl excrement in the city as a whole was of lesser consequence, 23 and 32 per cent respectively of the 35 and 25 samples located in 1951 and 1952 being positive. Fortunately, only one such problem establishment was present in the community.

Household garbage (in containers and scattered) was the most frequent producer of positive substrates and represented more than 47 and 53 per cent of all positive substrates located during 1951 and 1952. This medium, because it was present within every block in the community in small volumes, serves as an example of category (b). The ubiquitous distribution and close proximity to human habitation of garbage makes it a major cause of the undesirable close association between *Musca domestica* and man.

Inasmuch as dump sites of copious fly production were of infrequent occurrence in Charleston, the qualitative measurement of fly breeding founded upon the percentage of media infested without regard to the volume of the substrate serves as a reliable yardstick for appraising the importance of the different substrates in creating the local fly problem. It should be pointed out, however, that while the operation of a control program affected over-all fly production within the city, its influence was disproportionately greater with reference to the findings for garbage. One of the principal control tactics concerned the routine treatment of garbage cans with a residual insecticide in the spring period, a measure which was not applied to other production sources with the same routine extensive coverage. Sanitation efforts likewise were directed more heavily toward refuse than against other sources. Some measure of these effects can be obtained from survey data obtained in the untreated communities wherein garbage composed 76 per cent of the total positive substrates detected and showed an infestation rate of 43 per cent. In comparison, the treated community yielded percentages of 53.8 and 24 for the same two respective phases during 1952.

In viewing the over-all data for Charles-

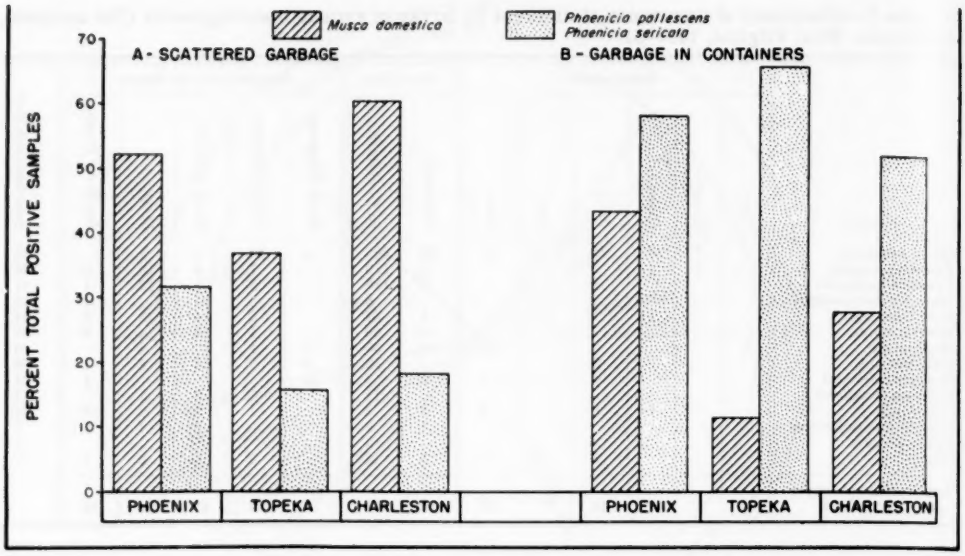

FIG. 5.—Relative frequency of occurrence of larvae of *Musca domestica* and blowflies *Phaenicia sericata*, *P. pallescens* in (A) scattered garbage, and (B) garbage in containers, Phoenix, Arizona; Topeka, Kansas; and Charleston, West Virginia.

ton, West Virginia, it is apparent that garbage both as to prevalence and the rate of infestation was the most important fly producing source within the community. In addition, this substrate supported a wider range of species than any of the remaining media, as evidenced by the fauna of 22 different flies which were produced from garbage in containers (Table 2).

These data agree with those reported for Savannah by Quarterman *et al.* (1949), but conflict with the general statement in the literature (Matheson 1950; Metcalf *et al.* 1951) that house fly production is chiefly the result of breeding in horse manure. Herms (1950) likewise places emphasis upon horse manure but qualifies the statement as relating to rural conditions. Available evidence now indicates that in urban areas household garbage forms the principal substrate for house fly production. Even in cities where horse excrement is available, *Musca domestica* may breed more readily in other fecal matter (e.g., chicken). Needless to state, the displacement of the horse as a major means of transportation has relegated fly production from this source to a minor role. Moreover, many cities lay stress upon the enforcement of animal ordinances but appear less prone to emphasize the need for establishing and maintaining adequate refuse storage, collection, and disposal practices. Apparently the house fly has adapted itself more readily to the change in city conditions than has man's thinking in regard to a problem which is essentially man made.

In regard to garbage, one of the principal findings observed concerned the relative rates of infestation of scattered garbage and garbage in containers by *Musca domestica* and the blow flies *Phaenicia sericata* and *P. pallescens*. The data revealed that *M. domestica* was found more frequently in scattered garbage than in garbage in containers. The blow flies, however, exhibited a reverse preference, both species of *Phaenicia* being taken more readily in garbage in containers. That such a relationship is not unique for Charleston is evidenced by similar results from Topeka, Kansas, and Phoenix, Arizona (Figure 5). It is of particular significance that in areas like Phoenix where house flies are conspicuously predominant, the blow fly group still infests contained garbage more frequently. At Charleston, the preponderance of *M. domestica* in scattered garbage remained true despite the prevalence of blow flies in the area. Why blow flies and house flies exhibit differences in their ability to infest garbage under these two conditions is not answerable from the present data.

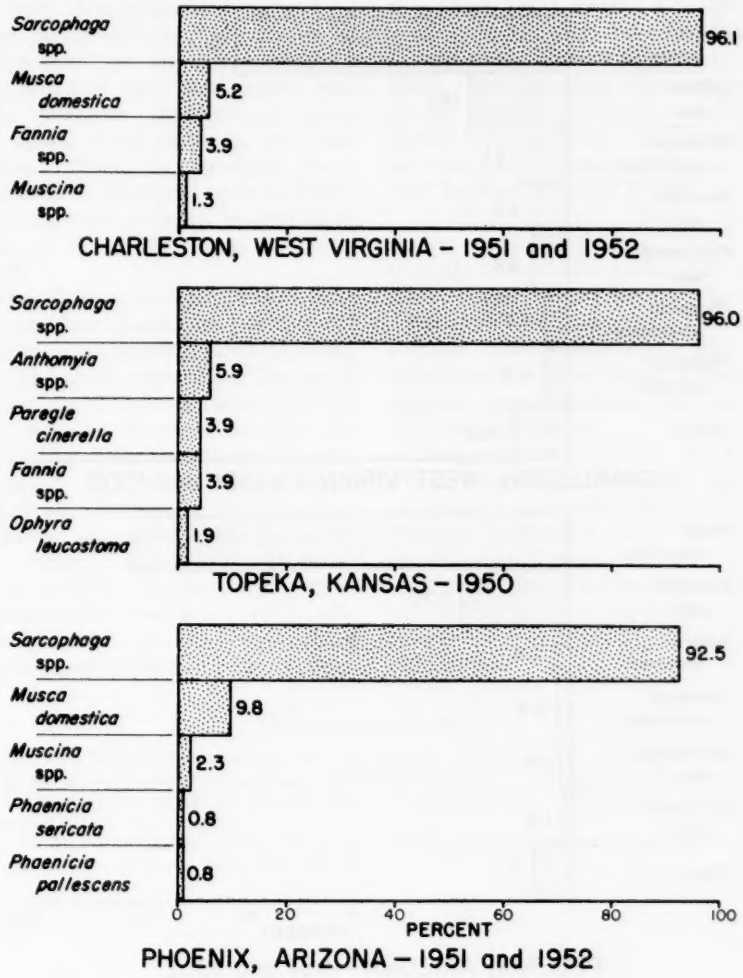

FIG. 6.—Percentage infestation of dog excrement by various fly larvae.

The general findings again implicate *Musca domestica* as the species which possessed the widest range of adaptability with reference to development in different media. The house fly was detected in 11 of the 13 classes of media whereas the blow flies *Phaenicia sericata*, *P. pallescens*, and *Phormia regina* were recovered from 9, 7, and 7 of the 13 media, respectively.

The results also show the flesh flies *Sarcophaga* to be the primary inhabitants of dog stools. In other excreta, particularly chicken excrement,[4] *Musca domestica* was the chief species produced. These data for excrement paralleled those from Topeka, Kansas, and Phoenix, Arizona (Figures 6 and 7).

Of the miscellaneous media, all except grass clippings provided suitable conditions for the development of 9 to 11 different species. *Musca domestica* was recovered most frequently from coffee grounds, but certain species such as *Phaenicia sericata* and *Phormia regina* infested several of the substrates on a relatively uniform basis.

The importance of specific substrates varied with the degree of sanitation practiced in the different residential zones; as the degree of sanitation was lowered, the number of different substrates increased. For example, in the high class area where a high degree of premises sanitation

[4] Refers to accumulated feces rather than individual droppings.

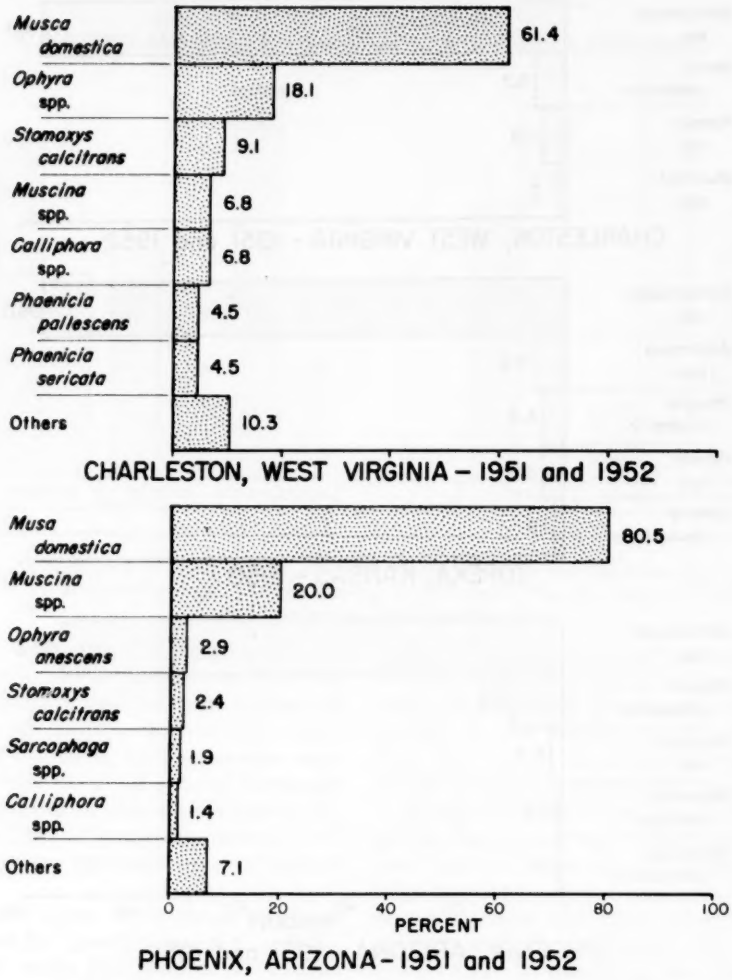

FIG. 7. Percentage infestation of chicken excrement by various fly larvae.

existed, only six types of positive substrates were located during the survey. Of these substrates, garbage in containers and dog excrement accounted for 75 per cent of all positive substrates found. In the middle class residential area, garbage in containers and dog excrement were still the important media detected but an increase occurred in the number of other positive substrates, such as grass clippings, dead animals, meat scraps, coffee grounds, etc.

In the residential areas characterized by a low degree of sanitation, the number of positive dog droppings decreased concurrently with an augmentation in the number of positive samples of human and fowl excrement. An appreciable increase in scattered garbage and other miscellaneous substrates also occurred in this area. Garbage and coffee grounds were the common breeding media in the business area. One reason for the infestations in coffee grounds was the large number of restaurants which stored putrescible wastes and moist coffee grounds in uncovered receptacles. Although coffee grounds were detected in residential areas, the volume of this medium in the individual container was insufficient for fly production.

Information on the breeding habits of various species not only serves as a guide in the execution of sanitation measures but also provides a useful aid in the chemical control of resistant flies. To

date, the only domestic fly resistant to chlorinated hydrocarbon insecticides is *Musca domestica*, a species which in Charleston infested less than 5 per cent of all the positive samples of grass clippings, meat, dead animals, and sea food wastes. Thus, in treating these media, a standard chemical such as DDT could be employed without jeopardizing the degree of house fly control in the community.

The survey data also indicate that only a minimal number of samples positive for house flies was encountered prior to June. Therefore, chemical control for the early spring period could include the use of any insecticide without concern for the resistance problem. This recommended procedure actually was practiced with success in 1952 at Charleston where resistance to dieldrin appeared in the house fly population during August 1951. In early spring 1952, dieldrin was still employed as a residual-larvicide treatment with subsequent chemical treatments consisting of space and residual sprays of other chemicals (e.g., DDT-DMC, CS-708).

SUMMARY.—Fly breeding surveys in Charleston, West Virginia, in 1951 and 1952 demonstrated that approximately 50 per cent of the positive substrates detected were garbage. Similar results were obtained at Phoenix, Arizona (1951–52), and Topeka, Kansas (1950).

In all three cities, *Musca domestica* infested scattered garbage much more frequently than it did garbage in containers. The reverse was true for the blow flies *Phaenicia sericata* and *Phaenicia pallescens*. *Sarcophaga* spp. was the chief inhabitant of dog stools whereas *M. domestica* predominated in accumulated chicken excrement.

Socioeconomic levels in Charleston, West Virginia, influenced the types of substrates available, the number of substrates increasing with the decline in premises sanitation.

Musca domestica exhibited the greatest versatility in breeding habits; this species was recovered from 11 of the 13 different substrates.

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Differences between a Resistant and a Non-Resistant Strain of the German Cockroach

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Heal *et al.* (1953) found that a field-collected strain of the German cockroach possessed an extreme degree of resistance to chlordane, and significant resistance to lindane and DDT. The cockroaches used in most of the tests were second- and third-generation progeny from an original culture obtained from Corpus Christi, Texas. Fisk and Isert (1953) have shown this same strain of German cockroach to be highly resistant to chlordane and dieldrin, and slightly resistant to three other insecticides, after being reared for nine generations without exposure to insecticides.

In March 1952, the writer was informed by W. D. Bedingfield of Corpus Christi, Texas, that difficulty was being encountered in that city in controlling the German cockroach with chlordane. A small culture of field-collected cockroaches was later shipped to the writer. It was necessary to rear these insects for several

[1] Acknowledgement is made to C. Y. Kramer, Statistical Laboratory, Virginia Polytechnic Institute, for making some of the statistical analyses.

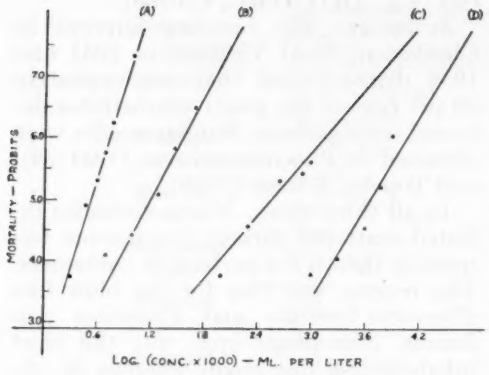

FIG. 1.—Mortality of adults from resistant and non-resistant strains of the German cockroach at the end of 10 days following treatment with chlordane. Non-resistant-strain males, (A); Non-resistant-strain females, (B); resistant-strain males, (C); and resistant-strain females, (D).

generations in order to get an adequate supply for testing purposes. In this paper some differences are presented between the third- and fourth-generation offspring of the strain from Texas, and a laboratory strain which had not been exposed to an insecticide. The criteria of comparison are: resistance to three insecticides, reproductive performance, size of empty egg cases, and weight of adults.

FORMULATIONS TESTED.—The forms of insecticides used were technical grade chlordane, pure tetraethyl pyrophosphate (TEPP), and lindane. Water suspensions of chlordane were prepared from acetone

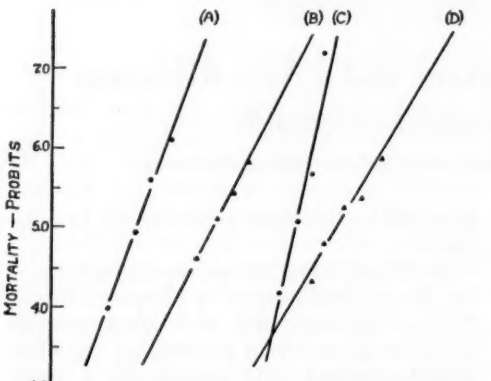

FIG. 2.—Mortality of adults from resistant and non-resistant strains of the German cockroach at the end of 4 days following treatment with lindane. Non-resistant-strain males, (A); non-resistant-strain females, (B); resistant-strain males, (C); and resistant-strain females, (D).

solutions of this material by use of the suspending agent, Emcol H65A.[2] Preliminary trials revealed that neither acetone nor the suspending agent exerted any deleterious effects upon the German cockroach at concentrations employed in this study. Solutions of TEPP were formed by addition of the pure material to distilled water. Water suspensions of lindane were prepared from acetone solutions of this material.

RESISTANCE TO INSECTICIDES.—The insects were reared in the same manner as previously employed for other strains (Grayson 1951). Cockroaches within

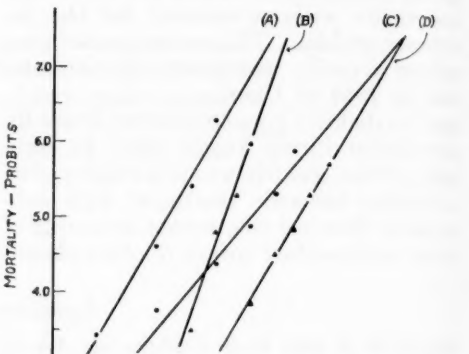

FIG. 3.—Mortality of adults from resistant and non-resistant strains of the German cockroach at the end of 4 days following treatment with TEPP. Non-resistant-strain males, (A); resistant-strain males, (B); non-resistant-strain females, (C); and resistant-strain females, (D).

known age limits were obtained by removing all adults from the stock cultures at intervals of 7 to 10 days. For treatment they were placed in small screen cages, from 20 to 30 per cage, and dipped in the insecticidal preparations at 30° C. Cockroaches treated with chlordane were dipped for a period of 20 seconds, and allowed to remain in the treated cages for 60 minutes following dipping before removal to recovery jars; whereas those treated with lindane or TEPP were dipped for 10 seconds and left in the treated cages for 15 minutes before removal to recovery jars. Mortality counts were made at the end of 3, 6, and 10 days following treatment with chlordane, and at the end of 2 and 4 days following treatment with lindane or TEPP. Dead and moribund

[2] Manufactured by the Emulsol Corp., Chicago, Illinois.

Table 1.—Comparative toxicities of three insecticides to resistant[1] and non-resistant strains of the German cockroach.

Insecticide[2]	Sex	Non-Resistant Strain		Resistant Strain		Order of Resistance	
		LD-50	LD-90	LD-50	LD-90	at LD-50	at LD-90
Chlordane	M	0.0034	0.0063	0.3800	2.100	111.7	333.3
	F	0.0165	0.0476	4.5500	14.870	275.7	312.3
Lindane	M	0.0103	0.0155	0.0595	0.076	5.7	4.9
	F	0.0242	0.0430	0.0940	0.185	3.8	4.3
TEPP	M	0.0575	0.1100	0.1120	0.165	1.9	1.5
	F	0.1530	0.3950	0.2650	0.512	1.7	1.2

[1] The resistant strain consisted of third- and fourth-generation roaches reared from a small culture received from W. D. Bedingfield at Corpus Christi, Texas.
[2] The values shown are in terms of ml. per liter for chlordane and TEPP, and grams per liter for lindane.

roaches were combined in the mortality counts. The criterion for regarding a specimen as moribund was inability to exhibit active locomotion.

The results are shown in figures 1 to 3 and in table 1. The regression lines were fitted to the points by the method of least squares (Bliss 1935). From four to six points were used to establish each line, and at each concentration the tests were usually replicated from three to six times.

REPRODUCTION.—The data for reproductive response of each strain were obtained from the performance of 72 females which were maintained in a constant-temperature cabinet at 30° C. and approximately 55 per cent relative humidity for a period of 105 days. They were grouped into 6 replicates of 12 females each. The different lots of females were reared in 1-gallon, glass battery jars with an adequate number of males. Tiers of pressboard were placed in each jar, and food and water were continuously made available. At appropriate intervals the nymphs and empty egg cases were removed.

The results are briefly summarized in table 2. The data were analyzed by the analysis of variance. Fewer nymphs per female and fewer nymphs per egg case were produced in the resistant strain than in the non-resistant strain. These differences were greater than would be expected at odds of 19 to 1.

EMPTY EGG CASES.—Measurements were made with a vernier caliper of the lengths and widths of 300 empty egg cases from each strain. These were made by each of three different individuals measuring 100 empty egg cases.

The results are shown in table 3. The empty egg cases produced within the resistant strain were smaller in both length and width than those produced within the non-resistant strain. The differences were greater than expected at odds of 19 to 1.

Table 2.—Reproductive performance during a 105-day period of adults from resistant and non-resistant strains of the German cockroach.

Strain	Average[1] Nymphs Produced	
	Per Female	Per Egg Case
Resistant	122.6[2]	34.7[2]
Non-resistant	138.9	37.1

[1] Average of 6 replicates of 12 females each.
[2] Significantly different (P = <.05) from non-resistant strain.

WEIGHTS OF ADULTS.—Adult cockroaches were weighed in lots of 20 on an analytical balance. Six lots each of males and females were weighed for each strain.

The results are shown in table 4. Male and female cockroaches in the resistant strain weighed less than the corresponding sex in the nonresistant strain. The differences were greater than expected at odds of 99 to 1.

Table 3.—Average[1] lengths and widths of empty egg cases produced by resistant and non-resistant strains of the German cockroach.

Strain	Length (mm.)	Width (mm.)
Resistant	7.8[2]	3.5[2]
Non-resistant	8.1	3.7

[1] Measurements were made on 300 empty egg cases from each strain.
[2] Significantly different (P = <.05) from non-resistant strain.

Table 4.—Average[1] weights of adult German cockroaches from resistant and non-resistant strains.

STRAIN	MALES (GM.)	FEMALES (GM.)
Resistant	1.1020[2]	2.0150[2]
Non-resistant	1.2053	2.2476

[1] Average of six replicates of 20 insects each.
[2] Highly significantly different (P = <.01) from non-resistant strain.

DISCUSSION.—The data presented here are in agreement with those reported by Heal *et al.* (1953) and Fisk & Isert (1953) in showing that the strain of German cockroach from Corpus Christi, Texas, possesses a high degree of resistance to chlordane. The order of resistance of this strain to chlordane is considerably greater than that reported for a DDT-selected strain to DDT (Grayson 1953). This is particularly true in the case of the males. The magnitude of resistance, originally and after nine generations of development without exposure to an insecticide (Heal *et al.* 1953, Fisk & Isert 1953), would suggest that the genetic basis for resistance to chlordane in the German cockroach is comparatively simple, *i.e.* restricted to one or only a few loci; and that in the chlordane-resistant strain the determinants for resistance are probably homozygous.[3] This contrasts with the apparent complex nature of DDT resistance in the German cockroach (Cochran *et al.* 1952). Experiments are currently being conducted in this laboratory for testing this hypothesis.

In all other comparisons (*i.e.*, nymphs produced per female, lengths and widths of empty egg cases, and weights of adults) significant differences were found between male and female cockroaches in the resistant strain from Texas and the corresponding sex in the non-resistant, laboratory strain. These changes in strain characteristics resulting from sustained use of chlordane in the field are similar to those reported from the use of DDT in selecting an insecticide-resistant strain of the German cockroach in the laboratory (Grayson 1953).

SUMMARY.—A small culture of a strain of the German cockroach reported to survive treatments with chlordane was obtained from W. D. Bedingfield at Corpus Christi, Texas. Roaches in the third and fourth generations from the original culture were compared with a non-resistant laboratory strain. The criteria of comparison were: resistance to three different insecticides, reproductive response, size of empty egg cases, and weights of adult roaches.

Data on the comparative toxicities of three insecticides to the resistant strain from Texas and the non-resistant, laboratory strain are presented. The resistant strain was found to be very highly resistant to chlordane (>100 times), moderately resistant to lindane (>3.8 times), and only slightly resistant to tetraethyl pyrophosphate (>1.2 times).

Fewer nymphs per female and fewer nymphs per egg case were produced in the resistant strain than in the non-resistant strain. The differences were significant (P = <.05).

The empty egg cases produced in the resistant strain were smaller in both length and width than those produced in the non-resistant strain. The differences were significant (P = <.05).

The weights of male and female cockroaches in the resistant strain were less than those of the corresponding sex in the non-resistant strain. The differences were highly significant (P = <.01).

[3] Acknowledgment is made to Max Levitan, geneticist at the Virginia Polytechnic Institute for advice in advancing this hypothesis.

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Control of Thrips and Leafhopper on Peanuts

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Thrips and leafhopper have attracted considerable attention on peanuts during recent years in the Georgie-Florida-Alabama area. Seedling peanuts are attacked early in the season by thrips, *Frankliniella fusca* (Hinds), and to a lesser extent by *F. tritici* (Fitch). During midsummer injury from potato leafhopper, *Empoasca fabae* (Harr.), is quite common. Until recently, little was known regarding the importance of these insects as pests of peanuts.

Thrips injury to peanuts was noted in Florida as early as 1917 (Watson 1918). Poos (1941) referred to thrips injury to peanuts causing a condition sometimes called "pouts." However, Shear & Miller (1941) called attention to confusion arising from the term "pouts" and suggested its discontinuance. Poos (1945) reported successful control of thrips with 2 per cent DDT dust. Poos *et al.* (1947) found that control of thrips with DDT and BHC dusts and sprays resulted in increased yield of peanuts in the Virginia-Carolina area.

The potato leafhopper has been considered a pest of peanuts at least since the publication of results of research by Poos & Batten (1937) on control of potato leafhopper on peanuts in Virginia. Other research indicating the importance of this insect on peanuts was the published results of Batten & Poos (1938), Miller (1942), Poos *et al.* (1947), Wilson & Arant (1949), Arant (1951), and others. In some of the earlier investigations it was not possible to evaluate accurately the relative importance of leafhoppers and *Cercospora* leafspot.

Research in Alabama on insecticidal control of thrips and potato leafhopper on peanuts was begun at the Wiregrass Substation in 1946 and has continued to the present. Summarized results for the period 1946 to 1950 inclusive are herein reported.

Procedure.—*Plot Layout.*—The plot layout varied somewhat from year to year depending upon the nature of the experiment. Preliminary tests were conducted on plots 6 to 8 rows wide, varying in length from 33⅓ to 80 feet. The shorter length was used where applications were made with hand equipment and the longer ones where tractor equipment was employed. Plots were separated by alleys 4 to 6 rows wide to act as buffers against drifting insecticidal dusts. Treatments were replicated 4 to 5 times in randomized complete blocks. Blocks of plots were separated by alleys 15 to 25 feet in width.

After preliminary tests were made, more promising treatments were tried in field-scale experiments. Plots were usually 12 to 24 rows wide and extended the length of the field. The treatments for the various field plots were located at random, and all the treatments in an experiment were considered a block. Other blocks of the same treatments were located in the same or in other fields until treatments had been replicated several times. Replications in field-scale experiments varied from 3 to 15 in number.

Application of Insecticides.—Insecticides were applied for the most part as dusts, although sprays were used in some preliminary experiments. In the earlier experiments all materials were applied with hand dusters or sprayers. Later, tractor dusters were used. In field-scale experiments all the insecticides were applied with tractor-mounted dusters. The rate of application of dust was 20 to 25 pounds per acre per application with both hand and tractor dusters. Where sprays were used, the rate was approximately 75 to 100 gallons per acre per application. With few exceptions, all insecticides were applied while the foliage was dry and the air relatively calm. When there was heavy rainfall within 24 hours, applications were usually repeated. When leaf-feeding caterpillars appeared in the experimental area, all plots including the checks were treated with cryolite at approximately 25 pounds per acre in order to eliminate or at least minimize the effect of these insects.

Insect Infestation Records.—Infestations of thrips and leafhoppers were taken at

[1] The writer acknowledges substantial contributions by Dr. Coyt Wilson to research reported in this paper. Dr. Wilson was formerly Plant Pathologist but is now Assistant Dean and Director, Alabama Polytechnic Institute School of Agriculture and Agricultural Experiment Station. He was in charge of that part of the work relating to control of *Cercospora* leafspot. Credit is also due Dr. Marvin E. Merkl, now with the U. S. Entomology Research Branch, for assisting with the field work in 1950.

intervals during some of the experiments. Thrips populations were determined by removing 20 tips of the peanut plant and counting the thrips present. A tip 2 inches in length was selected at random from each of 20 plants in one of the inner rows of each plot. Leafhopper infestations were also determined from the tips examined. In addition, leafhoppers were collected by sweeping with an insect net to determine abundance of the insects. For each count, 10 sweeps of the insect net were made when the air was reasonably calm and the foliage dry. The average of two counts on each plot was recorded as the infestation. Nymphs and adults were counted separately but are reported together in this paper.

Yield Records.—Several methods of harvesting were used to determine yield of peanuts receiving various treatments. In the early experiments on small plots, the peanuts were dug, picked green by hand, and weighed. The pods remaining in the soil were removed by hand and also weighed. In later experiments the peanuts were dug, sacked, transported to a stationery peanut picker, and picked by the machine while green. Either one or two of the inner rows of each plot was used for harvest records. Frequently, though not always, half of the record area was harvested at one date and the other half 1 week to 10 days later to measure the effect of time of harvest on yield of peanuts receiving different treatment.

In field-scale experiments, the peanuts were plowed up and shaken with machinery used generally for this purpose on the farm. In some of the experiments the pods were allowed to dry in windrows. The peanuts were then picked by a portable picker as it was moved along the windrow. In other field experiments the peanuts were dried in small piles or stacks. The pods were then removed by conventional type pickers. Yield records were taken only from rows near the center of the plot. The size of the area varied in different fields.

Regardless of method of harvesting, a composite sample of peanut pods was taken from each plot at the time the peanuts were picked. Usually this sample was 1 pound in size. The samples were removed to the laboratory and dried to constant weight in an electric dryer. The drying percentage was then applied to the weight of green peanuts harvested in order to calculate the yield of dry peanuts per plot. All yields were adjusted to 7 per cent moisture content for uniformity. The sample of peanuts from each plot was shelled and studied for quality and for percentage of sound, mature kernels.

RESULTS.—Results of the experiment were measured in terms of insect infestations and yield of peanuts. In the earlier work, major emphasis was placed on insect infestations to determine the effectiveness of various insecticidal treatments. Later, most of the emphasis was on yield of peanuts in order to determine the practicability of control. Since both infestation and yield records are not available from all experiments, the results are reported separately.

Leafhopper Infestation on Spanish Peanuts.—DDT, toxaphene, and DDT-sulphur-copper mixture were highly effective in reducing the infestation of leafhopper on Spanish peanuts (Table 1). Three applications of these materials reduced the insect counts to approximately 2 per 10 sweeps of an insect net as compared to 16 on the untreated checks. These reductions were highly significant. BHC dust containing 2 per cent gamma isomer and 5 per cent chlordane dust were much less effective.

Thrips and Leafhopper on Runner Peanuts.—Studies were made of thrips and leafhopper infestation on runner peanuts in several experiments. Results of tests made in 1946 and 1947 are presented in Tables 2, 3, and 4.

Table 1.—Leafhoppers on Spanish peanuts on August 2, 1947, following applications of insecticidal dusts, four replications.

TREATMENT[1]	AVERAGE NUMBER LEAFHOPPERS PER 10 SWEEPS WITH INSECT NET
Undusted check	16.1
2% DDT	2.4
2% BHC (gamma isomer)	11.0
20% toxaphene	2.4
5% chlordane	13.4
2% DDT in copper-sulphur[2]	1.8
LSD, 5 per cent level	2.5
LSD, 1 per cent level	3.5

[1] Dusted July 9, July 22, and August 1, with approximately 20 pounds per acre per application.
[2] 3.4 per cent metallic copper and approximately 87 per cent sulphur.

Table 2.—Infestation of thrips and leafhopper following applications of dusts to runner peanuts, experiment I, 4 replications, 1946.

Treatment[1]	Average Number[2]		
	Thrips per 20 Peanut Tips	Leafhoppers per 20 Peanut Tips	Leafhoppers per 10 Sweeps with Insect Net
Undusted check	38.6	4.8	34.4
3% DDT	15.1	0.4	5.5
1% rotenone	33.7	3.1	27.6
2% nicotine	55.9	2.6	24.9
20% sabadilla	21.9	1.7	13.1
LSD, 5 per cent level	11.6	2.6	8.5
LSD, 1 per cent level	16.2	—	11.9

[1] Dusted July 15 and 25 at rate of 25 pounds per acre.
[2] Average of counts made July 18 and 31.

The most effective materials tried in the control of thrips were DDT spray, 2 and 3 per cent DDT dust, and 20 per cent toxaphene dust. All of these materials reduced the population significantly below that on the untreated checks in all experiments. Usually the differences were highly significant. DDT spray at 0.75 pound per acre was much more effective than DDT dust at a slightly lower rate (Table 3).

Three plant derivatives and sulphur dust were much less effective for thrips control than DDT and toxaphene (Tables 2 and 4). The infestation on plots receiving 20 per cent sabadilla was significantly lower than on untreated checks. Where 2 per cent nicotine was used, the population of thrips was higher than where no insecticide was applied. Sulphur dust did not affect the population significantly.

DDT dust and spray, toxaphene dust, methoxychlor dust, and sabadilla dust were highly effective in reducing the population of leafhoppers on runner peanuts. On plots treated with sulphur dust, the leafhopper population was significantly lower than on the untreated checks, but the material did not give as good control as other insecticides. BHC failed to give satisfactory reduction in the population of leafhoppers on runner peanuts under the condition of the experiment (Table 4).

Table 3.—Thrips and leafhopper on runner peanuts following applications of dusts and sprays, experiment II, 4 replications, 1946.

Treatment[1]	Pounds per Acre	Average Number[2]		
		Thrips per 20 Peanut Tips	Leafhoppers per 20 Peanut Tips	Leafhoppers per 10 Sweeps with Insect Net
Untreated check	0.00	51.8	5.6	32.7
DDT spray	0.75	3.2	0.1	2.6
Sulphur dust	20.00	49.7	3.3	18.1
DDT dust	0.50	41.2	0.2	9.8
LSD, 5 per cent level		7.9	1.8	7.0
LSD, 1 per cent level		11.4	2.6	10.1

[1] Applications, June 27, July 9, July 19, July 27.
[2] Average of counts made July 10, July 15, July 25, Aug. 7.

Table 4.—Thrips and leafhopper on runner peanuts following dust applications of chlorinated hydrocarbons, 1947.

Treatment	Number of		Average Number[1]	
	Dustings	Replicates	Thrips per 20 Peanut Tips	Leafhopper per 10 Sweeps with Insect Net
Untreated check	0	4	174.3	7.9
2% DDT	4[2]	4	107.4	5.2
2% BHC (gamma isomer)	9[3]	4	53.9	6.0
2% DDT	7[3]	4	100.5	0.9
2% DDT	10[3]	4	109.7	1.0
LSD, 5 per cent level			26.3	2.5
LSD, 1 per cent level			36.9	3.5
Untreated check	0	2	114.8	18.5
3% methoxychlor	9[3]	2	117.5	1.0
20% toxaphene	9[3]	2	24.7	0.5

[1] Average of counts made June 4, June 11, June 26, July 2.
[2] Dusted May 27, June 4, June 11, and June 26 at the rate of 20 pounds per acre.
[3] Only the applications of May 27 and June 4, 11, and 26 were made during the period of infestation counts.

Table 5.—Effect of four applications of insecticides applied for leafhopper control on yield of Spanish peanuts, 1947.

Treatment[1]	Pounds of Dry Peanuts per Acre	
	Yield	Gain Over Check
Undusted check	996	—
2% DDT—inert	1262	266
2% BHC (gamma isomer)—inert	1058	62
20% toxaphene—inert	1463	467
5% chlordane—inert	1011	15
2% DDT in sulphur-copper	1421	425
LSD, 5 per cent level	189	
LSD, 1 per cent level	261	

[1] Applications made July 9, July 22, August 1, and August 13 with approximately 20 pounds per acre.

Table 6.—Effect of insecticides applied for control of thrips and leafhopper on yield of Spanish peanuts, 1948.

Treatment[1]	Number of Dustings	Pounds of Dry Peanuts per Acre	
		Yield	Gain Over Check
Undusted check	0	1439	—
20% toxaphene—inert	6[2]	1840	401
20% toxaphene—inert	4[3]	1750	311
10% toxaphene—inert	4[3]	1643	204
2% DDT in sulphur-copper	4[3]	1866	427
5% DDT; 2% DDT—inert	2; 4[4]	1655	216
2% DDT—inert	4[3]	1613[5]	174[5]
LSD, 5 per cent level		219	
LSD, 1 per cent level		303	

[1] Approximately 20 pounds per acre per application.
[2] Dusted May 28 and June 18 for thrips and July 14, July 23, August 3, and August 13 for leafhopper.
[3] Dusted July 14 and 23 and August 3 and 13 for leafhopper; also leafspot where sulphur-copper was included.
[4] First two dustings, 5% DDT; last four, 2% DDT.
[5] Yields available on two replicates only; these data not used in analysis of variance.

Effect of Thrips and Leafhopper on Yield of Spanish Peanuts.—Results of an experiment on the control of leafhopper on Spanish peanuts in 1947 are presented in table 5. Results of a similar experiment on thrips and leafhopper control in 1948 are presented in table 6.

All insecticides tried in these experiments resulted in significant increases in yield of peanuts with the exception of 2 per cent gamma isomer of BHC and 5 per cent chlordane dusts. Where six applications of the insecticides were applied for control of both thrips and leafhopper, the yields were not significantly greater than where four applications were made for leafhopper control. Two per cent DDT in a mixture containing 3.4 per cent copper and approximately 87 per cent sulphur was more effective in increasing yield than 2 per cent DDT in an inert carrier. The additional increase in yield was attributed to control of *Cercospora* leafspot. Gains from effective treatments ranged from 204 to 467 pounds of peanuts per acre.

Effect of Thrips and Leafhopper on Yield of Runner Peanuts, 1947 and 1948.—In two replicated experiments conducted in 1947 and 1948, 2 per cent DDT, 2 per cent DDT plus sulphur-copper, 10 per cent toxaphene, and 20 per cent toxaphene dusts were highly effective in the control of leafhopper on runner peanuts (Tables 7 and 8). Plots dusted with these

Table 7.—Effect of four applications of DDT with and without fungicide on yield of runner peanuts, 1947.

Treatment[1]	Pounds of Dry Peanuts per Acre	
	Yield	Gain Over Check
Undusted check	1792	—
Sulphur-copper dust[2]	2053	261
2% DDT inert dust	2131	339
2% DDT sulphur-copper	2236	444
LSD, 5 per cent level	258	
LSD, 1 per level	354	

[1] Dusts applied July 10, July 21, August 2, and August 13 with approximately 25 pounds per acre.
[2] Contained 3.4 per cent copper and approximately 87 per cent sulphur.

materials yielded 224 to 1,350 more pounds of peanuts per acre than untreated checks. Where 5 per cent DDT or 20 per cent toxaphene was applied twice for thrips control early in the season and 4 times later in the summer for leafhopper control, there was no significant increase in yield over plots treated only 4 times for leafhopper control (Table 8). It appeared from these results that four applications of DDT or toxaphene applied during the last of July and first part of August were effective in controlling leafhopper and increasing yield of peanuts

Table 8.—Effect of insecticides applied for control of thrips and leafhopper on yield of runner peanuts, 1948.

Treatment[1]	Number of Dustings	Pounds of Dry Peanuts per Acre	
		Yield	Gain Over Check
Undusted check	—	2366	—
20% toxaphene	6[2]	2679	313
20% toxaphene	4[3]	2831	465
10% toxaphene	4[3]	2718	352
2% DDT in sulphur-copper	4[3]	3716	1350
5% DDT; 2% DDT	2; 4[4]	2727	361
2% DDT	4[3]	2590	224
Outside check[5]	—	2122[5]	−244[5]
LSD, 5 per cent level		313	
LSD, 1 per cent level		428	

[1] Applied at approximately 20 pounds per acre per application.
[2] Dusted May 28, June 18 for thrips and July 14, July 23, August 3, August 13 for leafhopper.
[3] Dusted July 14, July 23, August 3, August 13 for leafhopper; also leafspot where sulphur-copper was included.
[4] First two dustings, 5% DDT; last four, 2% DDT.
[5] Four untreated plots adjoining experimental area; yields not included in analysis of variance.

over those on untreated checks. Two applications of the same materials applied to seedling peanuts for thrips control did not result in any significant increases in yield.

Field-Scale Control of Leafhopper in 1948.—Preliminary experiments indicated that 20 per cent toxaphene without a fungicide was as effective as 2 per cent DDT in a sulphur-copper mixture for control of leafhopper and increasing yields of peanuts (Table 5). Ten per cent toxaphene was as effective as 2 per cent DDT when both were applied without a fungicide (Table 6). However, toxaphene was not competitive in price with DDT. In a workable dusting program, it was necessary that the insecticide be in a mixture with sulphur or sulphur-copper to form a combination insecticidal-fungicidal dust. Sulphur in the mixture increased the cost very little, whereas the addition of copper was expensive. It was known that copper increased the efficiency of DDT-sulphur dust. A field-scale experiment conducted in 1948 was to determine the relative effectiveness of toxaphene-sulphur mixture as compared with toxaphene-sulphur-copper. Results of this experiment are presented in table 9. It will be noted that plots receiving the toxaphene-sulphur-copper produced significantly more peanuts than those receiving no treatment. The yield on plots receiving toxaphene-sulphur was intermediate between those on untreated checks and plots dusted with toxaphene-sulphur-copper mixture. The increases in yield over the checks resulting from treatment with toxaphene-sulphur averaged 223 pounds of peanuts per acre as compared with 368 pounds on the toxaphene-sulphur-copper plots.

Table 9.—Effect of toxaphene in mixtures with sulphur and sulphur-copper on yield of runner peanuts, 1948.

Treatment[1]	Pounds of Dry Peanuts per Acre	
	Yield	Gain Over Check
Undusted check	1424	—
10% toxaphene-sulphur[2]	1643	223
10% toxaphene-sulphur-copper[3]	1792	368
LSD, 5 per cent level	289	

[1] Dusted July 23, August 12, August 20, and August 27 with approximately 20 pounds per acre.
[2] 65 per cent sulphur.
[3] 65 per cent sulphur and 3.4 per cent copper.

Table 10.—Effect of various insecticides applied in inert carriers for leafhopper control on yield of runner peanuts, 1949.

Treatment[1]	Pounds of Dry Peanuts per Acre	
	Yield	Gain Over Check
Undusted check	1137	—
5% methoxychlor	1377	240
2% parathion	1590	453
2.5% DDT	1794	657
1% dieldrin	1259	122
1% parathion	1518	381
2.5% aldrin	1525	388
LSD, 5 per cent level	262	

[1] Dusts applied July 7 (light shower), July 18 (light shower), July 30 (heavy rain), August 2 (heavy rain), August 3, September 1 at approximately 20 poinds per acre.

Control of Leafhopper on Small Plots and Large Plots in 1949.—Results of experiments on the control of leafhopper with various insecticides on small plots are presented in table 10; yield records of peanuts treated with some of the same insecticides in mixtures with fungicides are presented in table 11. Ten per cent toxaphene and 2.5 per cent DDT alone or in mixtures with sulphur or sulphur-copper were the most effective insecticides tried. Two per cent parathion was also highly effective in terms of increased yield of peanuts. Plots

Table 11.—Effect of DDT and toxaphene in fungicidal and inert dusts on yield of runner peanuts, 1949.

Treatment[1]	Pounds of Peanuts per Acre			
	Second Digging		Average of Two Diggings[2]	
	Yield	Gain Over Check	Yield	Gain Over Check
Undusted check	598	—	1277	—
2.5% DDT in sulphur-copper[3]	1435	837	1685	408
2.5% DDT in sulphur[4]	1226	628	1769	492
2.5% DDT—inert	1280	682	1651	374
10% toxaphene in sulphur-copper[3]	1481	883	1838	561
10% toxaphene in sulphur[4]	1571	972	1823	546
10% toxaphene—inert	1113	515	1580	303
LSD, 5 per cent level	446		—[5]	
LSD, 1 per cent level	611			

[1] Dusts applied July 7 (light shower), July 18 (light shower), July 30 (heavy rain), August 2 (heavy rain) August 3, September 1, at approximately 20 pounds per acre.
[2] First digging, September 23; second, October 11.
[3] 3.4 per cent copper and 65 per cent sulphur.
[4] 65 per cent sulphur.
[5] Differences not statistically significant.

Table 12.—Effect of two insecticidal-fungicidal dusts on yield of runner peanuts on field-scale plots, 9 replications, Henry and Houston Counties, Alabama. 1949.

Treatment[1]	Pounds of Dry Peanuts per Acre	
	Yield	Gain Over Check
Undusted check	1591	—
10% toxaphene in dusting sulphur	2123	532
2.5% DDT in sulphur-copper	2239	648
LSD, 5 per cent level	221	
LSD, 1 per cent level	305	

[1] Four applications on each replicate at intervals of approximately 10 days during latter two-thirds of July and first of August, at 20 pounds per acre.

treated with 1 per cent parathion or 2.5 per cent aldrin also produced higher yields than the untreated checks. There was no significant increase in yield from the use of 1 per cent dieldrin or 5 per cent methoxychlor, although the gain from plots treated with methoxychlor approached significance. The gain from effective treatments ranged from 303 to 972 pounds of peanuts per acre in these experiments.

Results of an experiment conducted in 1949 on a field-scale basis with farmers in Henry and Houston Counties are presented in table 12. This experiment was done to test, on a farmer basis, treatments which had shown promise in small-plot areas. The differences in yields of peanuts between all treated plots and the undusted checks were highly significant. The differences between toxaphene-sulphur and DDT-sulphur-copper plots were not significant, although the trend was toward higher yields on the DDT-sulphur-copper plots. The yield of peanuts on plots treated four times with DDT-sulphur-copper was 2,239 pounds per acre as compared with 2,123 pounds where toxaphene-sulphur was used and 1,591 on the checks.

Table 13.—Effect of DDT and toxaphene in a fungicidal mixture on yield of runner peanuts in field-scale experiments, 15 replications, southeastern Alabama, 1950.

Treatment[1]	Pounds of Dry Peanuts per Acre	
	Yield	Gain Over Check
Undusted check	1396	—
2.5% DDT—3.4% copper 65% sulphur dust	1604	208
10% toxaphene—3.4% copper 65% sulphur dust	1776	380
LSD, 5 per cent level	186	
LSD, 1 per cent level	251	

[1] Three to 4 applications by farmers at 7- to 14-day intervals beginning the middle of July, at approximately 20 pounds per acre.

Effect of Insecticidal-Fungicidal Dusts in Field-Scale Experiments, 1950.—Results of field-scale experiments for the combined control of leafhopper and leafspot on farms in southeastern Alabama in 1950 in which a DDT-sulphur-copper mixture and a toxaphene-sulphur-copper mixture were used are presented in table 13. There was much variation in soil and in farming procedure in the different fields used. Average yields from 15 replications in several counties revealed significant increases in yield of peanuts resulting from the use of the dusts. The difference in yield between the plots receiving DDT and toxaphene was not significant, although the trend was toward higher yields where toxaphene was applied. Average yields of peanuts per acre from areas receiving different treatments were as follows: untreated check, 1,396 pounds; DDT-sulphur-copper, 1,604 pounds; and toxaphene-sulphur-copper, 1,776 pounds per acre.

SUMMARY AND CONCLUSIONS.—Replicated small-plot and field-scale experiments were conducted at the Wiregrass Substation of the A.P.I. Agricultural Experiment Station for control of thrips, *Frankliniella fusca* (Hinds), and potato leafhopper, *Empoasca fabae* (Harr.), from 1946 to 1950 inclusive. Two to 5 per cent DDT, 10 to 20 per cent toxaphene, and 2 per cent gamma isomer of BHC, applied at the rate of 20 pounds per acre, were highly effective in reducing the population of thrips. Twenty per cent sabadilla dust was moderately effective, and 1 per cent rotenone and 2 per cent nicotine were ineffective. Two to 5 per cent DDT and 10 to 20 per cent toxaphene were effective in reducing populations of leafhopper. Three per cent methoxychlor, 20 per cent sabadilla, and dusting sulphur also reduced the infestation of leafhoppers. Two per cent gamma isomer of BHC, 5 per

cent chlordane, 1 per cent rotenone, and 2 per cent nicotine were ineffective against this pest.

There were no consistent gains in yield of Spanish or runner peanuts from two applications of 10 per cent toxaphene or 5 per cent DDT applied at 10-day intervals for thrips control, beginning when the plants were in the seedling stage. In small-plot and field-scale experiments, Spanish and runner peanuts receiving four applications of 2 to 2.5 per cent DDT or 10 to 20 per cent toxaphene at the rate of 20 pounds per acre during July and August for leafhopper control yielded significantly more peanuts than untreated checks. Where the insecticide was used in a mixture with 3.4 per cent copper and a minimum of 65 per cent sulphur, the yields were usually significantly greater than where the insecticides were applied without the fungicide.

The treatment recommended as a result of this research consists of an insecticidal-fungicidal dust containing either 2.5 per cent DDT or 10 per cent toxaphene in a mixture with 3.4 per cent copper and at least 65 per cent sulphur. Treatment of runner peanuts should begin about the time of last cultivation near the middle of July. Four applications should be made at the rate of 20 pounds per acre at 7- to 10-day intervals. Treatment of Spanish peanuts is the same as for runners, except that the control program should begin 2 to 3 weeks earlier.

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Control of Willow Flea Weevil, Rhododendron Lace Bug and Red-Headed Pine Sawfly[1]

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Investigations on the comparative effectiveness and timing of application of various insecticides for control of insects attacking ornamental trees and shrubs have been conducted in Rhode Island during the past 5 years. The results of 4 years' work involving 22 insect and one mite species have been published (Kerr 1950, 1951, 1952, 1953). The present report is another contribution in the series and concerns studies completed in 1953 on the willow flea weevil, *Rhynchaenus rufipes* (Lec.), the rhododendron lace bug, *Stephenitis rhododendri* Horv., and the red-headed pine sawfly, *Neodiprion lecontei* (Fitch).

MATERIALS.—The particulars concerning the insecticides and dilutions used in each experiment are given in tables 1 to 3. All were wettable powders and included 50 per cent DDT, 50 per cent methoxychlor, 25 per cent lindane and 25 per cent malathion. A wetting, spreading and sticking agent,[2] at the rate of 4 ounces in 100

[1] Contribution No. 831 from the Rhode Island Agricultural Experiment Station, Kingston.

[2] Triton B-1956, a modified phthalic glycerol alkyd resin.

gallons of water, was used with each dilution of insecticide. All materials were applied as sprays with a conventional, power-operated, hydraulic sprayer and spray gun, except in the experiment involving the red-headed pine sawfly. A hand-operated, compression sprayer was used in this experiment.

FIELD STUDIES.—*Willow flea weevil.*—In Rhode Island this insect is often found in destructive numbers wherever the laurel willow, *Salix pentandra*, grows. Ordinarily it does not become a problem on the more popularly grown weeping willow, *S. babylonica*, except in areas where the two species of willow grow in close proximity.

In 1951 and 1952, the first overwintered adults were observed on April 30. In 1953, they appeared on April 29. On these dates few weevils were found, but by mid-May considerable numbers were present. During all three seasons some of the adults lingered until late in July, the latest date during which they were present being July 27, 1953. August 11, 1953, was the earliest date on which adults of the new generation were found.

Experiments were undertaken on both weeping willow and laurel willow. In 1951, 16 days after the adults began to emerge from hibernation, weeping willow trees averaging 17 feet in height were sprayed with 1 and 2 pounds of DDT, respectively, per 100 gallons of water. Although periodic examination for 11 weeks following treatment revealed the complete absence of adults on the leaves of the treated trees, there were well-developed larval mines in the leaves of both treated and untreated trees on July 31. At that time, 91 per cent of the leaves of the untreated trees contained one or more mines, while 46 per cent and 37 per cent, respectively, of the leaves sprayed with the greater and lesser concentrations of DDT showed larval mines. This indicates that some eggs were deposited soon after the adults emerged from hibernation. This is contrary to the results of Weiss & Lott (1921) and Nash (1934) who report that oviposition begins about 1 month after the adults appear in the spring.

In 1953, experiments were conducted on laurel willow trees averaging 12 feet in height. Each insecticide was applied to 10 trees on May 4 and May 19 at the rates indicated in table 1. On June 8 and June 22, five of the trees in each treatment were sprayed again. Data on control were obtained during the period of July 27 to August 5 when 100 random leaves from each of the trees were examined for larval injury. The results are presented in table 1. Both DDT and methoxychlor were effective in controlling the insect. Four applications of insecticide, even at the lesser concentration, resulted in fewer injured leaves than two applications. While two applications of either insecticide were not sufficient to prevent larval injury to some of the leaves, the number of mines per injured leaf was considerably less than that of the untreated trees.

Table 1.—Control of willow flea weevil with insecticides. South Kingstown, R. I. May-August, 1953.

Material	Pounds in 100 Gallons Water	Applications	Per Cent Leaves Mined	Mines per Injured Leaf
DDT 50% WP	2	2	17.9	2.8
	2	4	0.0	0.0
	1	2	22.4	3.0
	1	4	0.6	1.0
Methoxychlor 50% WP	2	2	28.4	1.9
	2	4	0.0	0.0
	1	2	37.0	3.2
	1	4	1.5	1.1
Check			100.0	11.4

Rhododendron lace bug.—This insect is one of the most serious pests of rhododendron in Rhode Island. During 1953 its seasonal history was similar to that reported by Herrick (1935), except for the time of appearance of the various stages.

Table 2.—Control of the rhododendron lace bug with insecticides. South Kingstown, R. I. June, 1953,

Material	Pounds in 100 Gallons Water	Per Cent Control
DDT 50% WP	2	100.0
	1	100.0
	0.5	99.9
Methoxychlor 50% WP	2	100.0
	1	100.0
	0.5	99.8
Lindane 25% WP	1	100.0
	0.5	96.8
	0.25	90.1

The overwintered eggs began to hatch on June 1. On June 24 adults of the first generation began to appear. Adults of the second generation were seen first on July 28.

The experiment was conducted on clumps of rhododendron plants, *Rhododendron maximum* L., averaging 10 feet high, 17 feet long and 12 feet deep. The materials listed in table 2 were applied on June 4. On June 29, data on control were obtained by examining 300 leaves of the previous year's growth in each treatment for live nymphs and adults. On the basis of active ingredient, all three insecticides were equally effective for controlling the first generation of lace bugs. Plants sprayed with the 1- and 2-pound rates of DDT and methoxychlor and the 1-pound rate of lindane remained free of the second generation also.

Red-headed pine sawfly.—This insect is a sporadic but extremely destructive pest of young pines. Its seasonal history corresponds to that outlined by Middleton (1921). During 1953, oviposition began in the experimental area on May 20. By June 15 hatching of the eggs was in progress. Almost all larval development was completed by July 29. A second brood did not appear during the remainder of the season.

The experiment was conducted on Scotch pine, *Pinus sylvestris*, approximately 6 feet in height and heavily infested with an average of 199 sawfly larvae per tree. The larval instars represented were the third, fourth and fifth. Each dilution of insecticide was applied to 4 trees on July 8. Data on control were obtained on July 10 when the trees were examined for live larvae. The results presented in table 3 show that all three insecticides used were effective in controlling the insect. Malathion was considerably more rapid in action than DDT or methoxychlor.

Table 3.—Control of the red-headed pine sawfly with insecticides. Portsmouth, R. I. July, 1953.

Material	Pounds in 100 Gallons Water	Per Cent Control
DDT 50% WP	2	100.0
	1	97.2
Methoxychlor 50% WP	2	100.0
	1	99.2
Malathion 25% WP	4	100.0
	2	99.7

Both DDT and methoxychlor were effective for controlling the willow flea weevil. Four sprays, each of which contained 1 pound of either insecticide as a wettable 50 per cent powder in 100 gallons of water, applied 5, 20, 39 and 53 days after adult emergence began on April 29, provided almost complete control. The two earlier sprays, even though containing twice the above-stated amount of insecticide, were not sufficient to prevent oviposition and subsequent larval attack on some of the leaves because the over-wintered adults lingered until late in July. Delaying the first of two applications of insecticide until 16 days after the adults began to emerge from hibernation also resulted in substantial larval mining.

Fifty per cent DDT, 50 per cent methoxychlor and 25 per cent lindane were effective for control of the rhododendron lace bug. The minimum effective amount of all three insecticides was 1 pound in 100 gallons of water. One spray applied in early June when the over-wintered eggs were hatching provided control of the first generation and prevented re-infestation by the second generation of the insect.

Fifty per cent DDT, 50 per cent methoxychlor and 25 per cent malathion were effective for control of the red-headed pine sawfly. As little as 1 pound of any of the insecticides in 100 gallons of water was sufficient when applied to third, fourth and fifth instar larvae in early July.

SUMMARY.—The comparative effectiveness of several insecticides, and the timing of such pesticide applications, was investigated in field tests involving three insects attacking ornamental trees and shrubs.

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Horn Fly Control with Chlorinated Insecticides[1]

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The work herein reported was begun in 1952 mainly as a result of reports of a few ranchers that DDT was not as effective as formerly in controlling horn flies on cattle. Some tried other insecticides or added BHC to their DDT formulation. While re-evaluating control with DDT, it was deemed desirable to test several of the newer chlorinated insecticides to determine their effectiveness against horn flies.

In an earlier report on horn fly control in Wyoming, Denning & Pfadt (1950) arrived at a recommendation of 1.5 per cent DDT water suspension spray on range herds and 1.0 per cent methoxychlor water suspension spray on dairy herds. They sprayed nearly 90 herds in five areas in the southeastern part of the state, from 1946–49, applying 1 to 2 pints of insecticide per animal to the top and underline at 150 pounds pressure. DDT wettable powder, 1.5 per cent gave an average of 27.2 days' protection while 1.0 per cent methoxychlor gave 22.5 days' protection.

METHODS.—During the summers of 1952 and 1953, 69 herds were sprayed with various concentrations of DDT, DDT-BHC, toxaphene, CS-708 dieldrin, heptachlor, Q-137, methoxychlor, and sulphoxide-pyrethrins. Only wettable powders were used since previous comparisons (Matthysse 1946, Eddy & Graham 1949) had shown them to be superior to emulsifiable concentrates for horn fly control. Sprays at the rate of $1\frac{1}{2}$ to $2\frac{1}{2}$ quarts per animal were applied to the topline only at 200 pounds pressure. Treated herds were examined as nearly as possible at weekly intervals and control was considered as ended when the herd averaged 25 or more flies per animal. Counts were taken in the morning when possible.

All treated herds except four were in the vicinity of Wheatland, Wyoming, which has an elevation of 4700 ft. The horn fly population in that area generally averages between 200 and 1,000 flies per adult animal in untreated herds from the latter part of June through the first half of September, the largest numbers occurring during August and September. Bulls may carry several thousand flies.

Sprayed herds consisted of 58 Herefords, 6 of Angus, and 5 of dairy breeds. Three of the dairy herds were treated with methoxychlor, the other two with Q-137.

DISCUSSION OF RESULTS.—Results are shown in table 1. DDT and CS-708 were the outstanding insecticides used. At concentrations of 0.5 per cent and 1.0 per cent and in combination with BHC, DDT nearly always (except once) gave control for at least 3 weeks, and usually 4 to 5 weeks. Increasing the concentration of DDT from 0.5 per cent to 1.0 per cent. did not prolong protection appreciably. The addition of BHC did not prolong protection. One herd was sprayed with 0.7 quart of 3.0 per cent DDT per animal, applied to the shoulder area only, under the assumption that concentrating the toxicant onto a smaller area which would be sooner or later contacted by all of the flies might give a longer residual action.

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Table 1.—Control of horn flies with various insecticides, 1952–1953.

FORMULATION[1]	NUMBER OF TESTS	PROTECTION (DAYS)		AVERAGE FLIES PER ANIMAL AT CONCLUSION
		Range	Average	
Dieldrin, 0.06%	5	14–28	19.4	27
0.125%	1	14	14	26
CS-708, 0.5%	7	14–30	26.4	46
DDT, 0.5%	6	19–35	26.5	27
1.0%	7	20–36	28.6	71
1.0%+fused bentonite sulfur, 1 lb./100 gal.	1	21	21.0	54
3.0% "spot treatment"	1	21	21.0	59
0.5%+BHC .03%	5	14–30	23.4	40
Heptachlor, 0.125%	3	14–21	16.3	80
0.25%	2	13–14	13.5	30
Methoxychlor, 0.5%	3	20–49	30.0	34
Q-137, 1.0%	9	13–28	17.6	41
Sulphoxide-pyrethrins, 5%	1	7	7.0	34
Toxaphene, 0.5%	5	7–21	16.4	46
1.0%	8	7–27	19.8	42
1.0%+fused bentonite sulfur 1 lb./100 gal.	2	7–21	14.0	65
1.0%+fused bentonite sulfur 3 lbs./100 gal.	3	18–29	22.3	55

[1] Dieldrin 25% w.p. furnished by Julius Hyman & Co. Div., Shell Chemical Corp. CS-708 25% w. p. furnished by California Spray-Chemical Corp. DDT 50% w. p. and Q-137 25% w. p. furnished by Rohm & Hass Co. Heptachlor 25% w. p. furnished by Velsicol Corp. Methoxychlor 50% w.p. and DDT-BHC (Dupont Livestock Spray no. 30) furnished by E. I. du Pont de Nemours & Co. Toxaphene 40% w.p. furnished by Hercules Powder Co. Sulphoxide-pyrethrins furnished by S. B. Penick & Co. Fused bentonite sulfur furnished by Niagara Chemical Div., Food Machinery and Chemical Corp.

This treatment provided only 21 days' control. Except for one test, 0.5 per cent CS-708 consistently controlled horn flies for 4 weeks and was fully as effective as DDT. On one heavily infested herd that was surrounded by other heavily infested unsprayed herds, CS-708 maintained control for 27 days despite being subjected to downpours of rain totaling 4 inches during the week after treatment.

Other insecticides were less effective. Toxaphene was erratic, on three occasions giving only 7 days' control. The period of protection from toxaphene averaged 9 to 10 days less than with DDT at equal concentrations. Dieldrin gave surprisingly good control, 19.4 days, considering the low concentration used (0.06 per cent). It was deemed unwise to exceed this concentration, however, especially when small calves were with the herd, even though the calves were not sprayed directly in any of the tests and received only what spray might happen to drip or splash onto them. Once, when the concentration of dieldrin was upped to 0.125 per cent only 14 days control was obtained. Q-137 probably cannot be counted for more than 2 weeks' control under severe fly conditions. Methoxychlor is almost certainly not as good as the 30-day average protection figure would indicate. The test that gave 49 days' control was at Torrington, where for some unapparent reason flies were relatively scarce on dairy animals. The other two tests are probably more indicative of what can be expected with a normal fly infestation.

The addition of fused bentonite sulfur at rates of 1 and 3 pounds per 100 gallons of water apparently did not extend protection to any appreciable degree.

DDT seems to be as effective as ever in controlling horn flies. Some of the herds used in this work were the same as used by Denning & Pfadt (1950)and have been treated for horn flies during 7 of the past 8 years. In the present work, $1\frac{1}{2}$ to $2\frac{1}{2}$ quarts per animal of 0.5 per cent DDT gave 26.5 days' protection and the same amount of 1.0 per cent DDT spray gave 28.6 days' protection. Somewhere between these two figures is the concentration that would deposit the amount of actual toxicant per animal equal to that deposited from 1 to 2 pints of 1.5 per cent DDT applied by Denning and Pfadt, and that gave 27.2 days' control. Other comparisons that can be made between the two sets of data also do not indicate any build-up of resistance to insecticides by horn flies. Under Wyoming conditions, 3 to 4 applications of either 0.5 per cent DDT or 0.5 per cent CS-708 at a rate of approximately 2 quarts per animal gave excellent seasonal control of horn flies,

i. e., mid-June to mid-September.

Back-rubber units of the type recommended by Rogoff & Moxon (1952) are now being used rather widely in several sections of the state and are doing a good job in open country where watering places are few. However, spraying with power equipment is still preferred by many, especially by those who have the equipment and whose animals are comparatively easy to round-up. From limited observations, back-rubber units have yet to prove their worth in rough, brush, or tree-covered grazing land and in places where cattle have access to a considerable water frontage.

SUMMARY.—DDT 0.5 per cent and 1.0 per cent and CS-708 0.5 per cent applied at the rate of 2 quarts per animal were the most effective of several insecticides tested as residual sprays for horn fly control. Each gave approximately 4 weeks' protection and were superior to dieldrin, heptachlor, Q-137 sulphoxide-pyrethrins, and toxaphene at the concentrations used.

The protection period was not appreciably prolonged by increasing the concentration of DDT from 0.5 per cent to 1.0 per cent, by the addition of 0.03 per cent gamma isomer of BHC to 0.5 per cent DDT, or by the addition to toxaphene and DDT of fused bentonite sulfur at the rates of 1 and 3 pounds per 100 gallons water.

There was no evidence of insecticide resistance in horn flies on herds that have received treatment in 7 of the past 8 years.

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The Possible Use of Microorganisms in the Control of the Great Basin Tent Caterpillar[1]

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Bitterbrush, *Purshia tridentata* DC., is the most important range browse east of the Sierra Nevada-Cascade Divide in California (Hormay 1943). It is heavily utilized by deer, sheep, and cattle. Hormay states that on large areas this valuable range browse has been destroyed or damaged by several factors including repeated defoliation by the Great Basin tent caterpillar, *Malacosoma fragilis*, (Stretch). In many years large areas of the plants are completely defoliated by the insect. While the bitterbrush may survive a single defoliation and produce new growth and leaves in the same season, the new growth is frequently taken by grazing animals. This double defoliation greatly weakens the plant, and, if repeated the following year, may result in the death of the bitterbrush and its replacement by less desirable species. The problem of the deterioration of bitterbrush rangelands is of considerable importance in the management of these sites for sheep, cattle, and deer production. Inasmuch as tent caterpillars are known to be susceptible to several diseases, preliminary investigations were begun in 1952 to determine the possibilities of developing an economical control measure through the use of insect pathogens.

[1] Contribution from the Laboratory of Insect Pathology, Department of Biological Control, College of Agriculture, University of California, Berkeley and Albany.

[2] The authors gratefully acknowledge the advice and guidance of Dr. Edward A. Steinhaus; and the cooperation of Mr. Howard B. Smith of the Tahoe National Forest, California, in the field phases of the work.

Some 50 years ago an inquisitive entomologist tested the infectivity of what was presumably a polyhedrosis virus against a tent caterpillar. Following a description of the widespread effects of what he believed to be a bacterium or fungus, Davis (1903) reported "a healthy colony was readily infected by spraying the leaves near the tent with water in which the caterpillars dead from the disease had been placed and broken up. Nine days after being infected every caterpillar of the colony was dead." Describing the effects on populations of the eastern tent caterpillar, *Malacosoma americanum* (F.), Davis stated that in the spring of 1903, thousands of colonies in Pennsylvania, New York, and New Jersey were attacked and decimated by the disease.

Although there was no adequate description of the pathogen, it is quite probable that Davis was actually dealing with a polyhedrosis virus rather than with a bacterium or a fungus. This is indicated by his failure to achieve cultivation of the pathogen, his picture of "smeared" and hanging caterpillars which are quite typical of virus-killed insects, and by the apparent 9-day incubation period he reported.

Howard & Fiske (1911) briefly discussed the role of a "wilt" disease in the natural control of tent caterpillars in connection with a similar disease in the gypsy and brown-tail moths. Shortly thereafter, Chapman & Glaser (1915) included *Malacosoma americanum* and *M. disstria* Hbn. in their "Preliminary List of Insects which have wilt. . . . " Glaser (1927) published measurements of the polyhedral bodies and data on the filterability of the virus from *M. americanum*. In 1949, Steinhaus reported the isolation and identification of the virus particles as well as the polyhedral bodies recovered from diseased specimens of the forest tent caterpillar, *M. disstria* Hbn. and the western tent caterpillar, *M. pluviale* (Dyar). Bergold and McGugan (1951) recovered polyhedral virus from *M. americanum*, *M. disstria*, and *M. pluviale* in Canada. Steinhaus (1951) then added *M. fragilis* to the list of tent caterpillars from which polyhedrosis viruses have been isolated. For several years, western forest entomologists have been aware of the important role of a disease in the control of the Great Basin tent caterpillar, (R.C. Hall, J. E. Patterson, J.M. Miller, 1949).[3] Wasser (1952)[4] isolated the pathogen from such an epizoötic and by light and electron-microscopy identified it as a polyhedrosis virus. She made certain cross-infectivity tests with virus from *M. disstria*, *M. fragilis*, and *M. pluviale* which suggested that there is no difference in susceptibility to the virus from the three sources in any of the insect species tested.

In 1950 and 1951, very high populations of the Great Basin tent caterpillar developed on Snowbrush, *Ceanothus cordulatus* Kell., in the Shaver Lake-Dinkey Creek, area, Fresno County, California. In 1952 an epizoötic of polyhedrosis virus disease occured in the population and destroyed a large proportion of the caterpillars. Observations made in the same area in 1953 indicated that the number of larval colonies had been reduced to about 10 per cent of the number occurring the preceding year. In addition, most of the 1953 population succumbed to virus-caused mortality in the early stages of larval development. In 1952; most of this mortality occurred in the last instar. Little, if any, damage by caterpillar defoliation was suffered by the host plant in 1953 compared to complete defoliation in 1952.

Judging from the above observations, it appears that the virus disease is (1) able to reduce populations of the caterpillar to a very low level, and (2) may prevent the development of a caterpillar population in an area which was the site of an epizoötic the previous year. Therefore, it would appear possible that if a virus disease could be introduced into a disease-free population of caterpillars, control for several years with only one treatment might be achieved. Since bitterbrush land is frequently of such low economic value that the cost of complete and repeated coverage with an insecticide is often prohibitive, the use of the disease may be a particularly suitable means of attacking the pest.

FIELD EXPERIMENTS.—In 1952 a stock of the virus material was obtained by spraying a heavy infestation of the California tent caterpillar, *Malacosoma californicum* (Pack.), in an abandoned or-

[3] Personal communication.
[4] Unpublished data by Harriette B. Wasser, University of California.

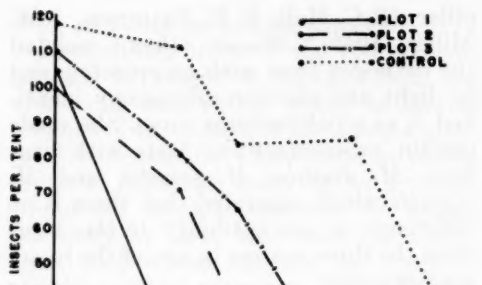

FIG. 1. Plot series I. Changes in tent caterpillar population following application of suspensions of polyhedrosis virus, 13×10^6, 5×10^6, and 0.5×10^6 polyhedra per ml. applied in 5 gallons of water to plots 1, 2, and 3 respectively. Treated June 24, 1952.

chard in Napa County, California. One week after spraying, the infected larvae were brought into the laboratory for rearing in wooden barriers until death. The dead and dying caterpillars were removed and triturated in distilled water. This suspension was calibrated by hemacytometer counts of polyhedral bodies as in the method described by Steinhaus & Thompson (1949). All field tests were conducted in the vicinity of Truckee, Nevada County, California on populations of *M. fragilis* infesting bitterbrush.

In June 1952, several small plots were sprayed with various concentrations of the virus. Sampling methods were not sufficiently adequate to lead to accurate estimations of population changes in the treated plots nor to comparisons between plots; but dying caterpillars were readily observed in all treated plots. Diagnosis by light microscope revealed the mortality was caused by a polyhedrosis. This mortality was grossly estimated at 80 per cent.

In the spring of 1953, a total of nine $\frac{1}{2}$-acre plots was treated with virus suspensions. The nine plots were treated in three series of three plots each, and the different series were treated 1 week apart. A $\frac{1}{2}$-acre control plot, sprayed with 5 gallons of water, was set up for each of the three series. Changes in the populations were estimated by removing a number of colonies from the plots and counting the insects remaining in the colonies. The numbers of insects per colony showed a greater uniformity during the earlier larval stages. As development proceeds, the gregarious habit of the caterpillars becomes weaker, the larvae spend a greater proportion of time feeding in scattered groups, and the brood from a single egg mass may split up to form two or more individual tents. In addition, later counts became less significant due to very heavy predation by a carabid, *Calosoma* sp. This beetle began appearing in great numbers about July 14, when the host caterpillars were in the III, IV, V instars, and destroyed or scattered the members of a large number of colonies. These difficulties in population estimations forced the discontinuance of the final series of plots.

Plot Series I.—These three plots were treated June 24 with the host insect in the I, II, III instars. The plots were located adjacent to each other, and the control plot was located at the upwind end of the line. Five gallons of suspension were applied with a back-pump sprayer. Virus concentrations expressed as polyhedra per ml. of final suspension were approximately 13×10^6, 5×10^6, and 0.5×10^6 for plots 1, 2, and 3, respectively.

The first insect mortality was observed on the eighth day following treatment. Counts made on the ninth day indicated a sharp drop in the population on plot 1, and a less rapid decrease in plots 2 and 3. The average number of insects per tent on all three plots continued to decrease, and between the 13th and 21st day the averages reached approximately 9, 21, and 12 for plots 1, 2, and 3 as compared with an average of 84 insects per tent on the control plot. Following the 21st day, the counts on the control dropped rapidly to an approximate average of 34 on the 28th day (Figure 1). As indicated above, the method of estimation used did not give an accurate reflection of the actual population on the plots during these last stages of larval development. This apparent descrease in population numbers on the control plot was primarily due to larval wandering which reduced the significance of counts of insects per tent. Some of this apparent decrease, however, resulted from the activites of the predacious beetle and was real.

That virus disease played little or no role in the untreated population was shown by continued examination of tents removed for counting and tents left on the plot, neither of which revealed deaths due to virus. In addition, several hundred tents were collected in the immediate area for mass production of the virus; close inspection of these tents at the time of collection showed that less than 1 per cent contained one or more insects with polyhedrosis symptoms.

On the treated plots, however, dead larvae were observed on almost every tent, and repeated microscopic examinations disclosed polyhedra in nearly every case. In the field, polyhedrosis-killed tent caterpillars can usually be readily identified by the smearing of the body contents over a tent or a twig, the bright organge color frequently observed in fresh smears of the cadavers, and the frequently observed posture of hanging by the prolegs.

Plot Series II.—The three plots in this series were treated July 1. They were located adjacent to each other, with the control plot nearby, and were several miles from Series I. The virus suspensions were applied with a 15-gallon power sprayer equipped with a 60-ft hose. Concentrations of virus were 6×10^6, 3.1×10^6, and 1.5×10^6 polyhedra per ml. for plots 4, 5, and 6, respectively. Virus caused mortality was evident on all plots on the 8th day; counts taken on the 9th day indicated the populations had been reduced to 46 per cent, 69 per cent, and 57 per cent of that occurring on the control plot. By 14th day, treated populations on plots 4, 5, and 6 were 6 per cent, 18 per cent, and 32 per cent of that found in the non-treated population (Figure 2). Destruction by the *Calosoma* beetle was so widespread that further counts were not possible. No disease was observed in the control plot.

DISCUSSION AND CONCLUSIONS.—It was found possible to initiate virus epizoötics in the tested population of the Great Basin tent caterpillar, *Malacosoma fragilis* (Stretch). The virus concentrations used were generally much heavier than the minimum found necessary for either the alfalfa caterpillar, *Colias philodice eurytheme* Bdvl. (Thompson & Steinhaus 1950) or the European pine sawfly, *Neodiprion sertifer* (Geoff.) (Dowden & Girth 1953). In addition, the rate of total suspension application (10 gallons per acre) was twice that used in the alfalfa caterpillar work.

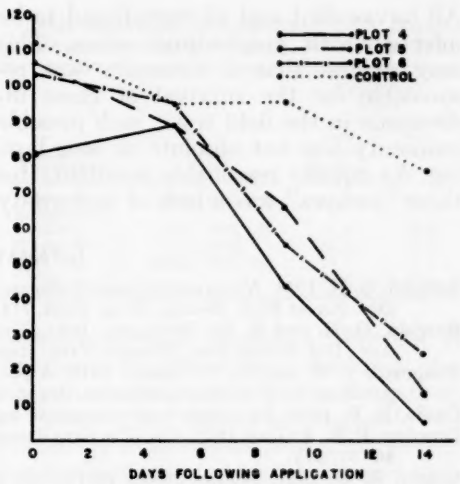

FIG. 2. Plot series II. Changes in tent caterpillar population following application of suspensions of polyhedrosis virus, 6×10^6, 3.1×10^6, and 1.5×10^6 polyhedra per ml. applied in 5 gallons of water to plots 4, 5, and 6 respectively. Treated July 1, 1953.

Bergold (1951) reports the results of infecting two very large laboratory populations of *Malacosoma disstria* with a polyhedrosis virus. In the one, in which the caterpillars were reared in wooden barriers, death "presumably through virus" reached 93.5 per cent. In the second, in which the caterpillars were reared indoors on trees, the insects dead of virus ranged from 3.8 per cent to only 10.4 per cent. He also reports individual larval feeding tests that indicated "a very high immunity of the forest tent caterpillar population used in the experiments." He believes, in regard to possible immunity, "The results of the feeding experiments, considered in relation to the occurence of various epidemics in various field populations, suggests a possible genetic relationship as was previously proposed in the case of the gypsy moth by R. W. Glasser."

Twenty-eight days following the treatment of plot 1 in the 1953 tests reported here, 45 larvae which had survived the treatment were removed and returned to the laboratory. These were set up individually in ½-pint cartons and fed bitterbrush foliage that had been dipped in a heavy suspension of polyhedral bodies.

All larvae died and all were found to be infected with polyhedrosis virus. This may suggest that if immunity was responsible for the survival of these individuals in the field tests, such possible immunity was not absolute or long-lasting. An equally reasonable possibility for these "escapes" was a lack of uniformity in the original field application. The question of variations in immunity among different populations of Great Basin tent caterpillars will require extensive field studies. Meanwhile, these preliminary results indicate that experimentation with commercial methods of application are warranted.

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Tolerance of Cucumbers to Component Compounds of Technical DDT

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Soon after DDT became available commercially, it was reported in some instances that the material was phytotoxic to curcurbits. Underhill (1945), Tate *et al.* (1945) and Dudley (1947) were among the workers reporting this DDT phytotoxicity. Certain varieties of cucumbers were particularly susceptible, and as a result, DDT, in many states has not been recommended for cucumbers. Carruth & Howe (1948) showed that DDT approaching aerosol grade was less injurious to squashes. Matthewman *et al.* (1950) reported that of 12 varieties of cucumbers tested, six showed tolerance to DDT, and six showed susceptibility. The six showing susceptibility also showed it toward the aerosol grade, while the other six did not.

In tests conducted at the Long Island Vegetable Research Farm, aerosol grade DDT, while lessening the phytotoxic effect to Niagara cucumbers, failed to lessen it appreciably. The possibility arose as to whether or not some material might work as a safening agent. Lucas & Hamner (1947), and Weaver (1948) were able to inactivate plant growth regulators with activated charcoal. Glass (1950) reported that parathion injury to apple foliage was reduced by the addition of carbon. This led to the choice of activated charcoal as a possible safening agent for DDT on cucumbers.

When activated charcoal[1] was included

[1] Aqua Nuchar provided by the West Virginia Pulp and Paper Company.

Table 1.—Vine length of Niagara Cucumbers as a criterion of phytotoxicity resulting from five applications of 2 per cent DDT dusts. Riverhead, New York, 1952.

GRADE OF DDT	RATIO OF CHARCOAL TO ACTUAL DDT	TREATMENT MEAN OF VINE LENGTH (INCHES)
Purified[1]	None	187.1
Purified	1–1	229.1
Technical[1]	None	62.1
Technical	1–1	208.1
Technical	3–1	276.9
Technical	6–1	279.9
Technical	12–1	278.8
Check		311.7
	L.S.D. 5 per cent —21.18	
	1 per cent —28.34	

[1] Furnished by the Geigy Company, Inc.

in a 2 per cent DDT dust formulation at the rate of three parts of charcoal to one part of actual DDT, the phytotoxic effect was greatly reduced as shown in table 1. A higher ratio of charcoal to actual DDT failed to give any further reduction in the phytotoxic effect, which indicated that a ratio of three parts charcoal to one part actual DDT gave the maximum safening effect.

The first application was made when the first true leaves were beginning to show. The other applications were made at weekly intervals, and the plant measurements were taken 1 week after the last application.

The chemical stability and insolubility in water of DDT is well known, but the safening effect of the charcoal raised the question as to whether or not the phytotoxicity was due to a very small water soluble fraction of the DDT. This was considered, since charcoal of this nature is used extensively in water purification, and in other industrial and chemical operations where undesirable odors, impurities, and colors are to be removed.

A greenhouse test was conducted to determine if a small water soluble fraction was the cause of the phytotoxicity. A spray suspension representing 6 pounds of a 50 per cent technical DDT wettable powder in 100 gallons of water was agitated for 3 hours and then filtered three times using a No. 12 Whatman filter paper (Filtrate A). The residue was resuspended in an equal volume of water for

Table 2.—Phytotoxic effects of DDT filtrates on Niagara cucumbers. Ithaca, New York, 1953.

TREATMENT	RATE DDT	TREATMENT MEAN: Vine Length (Inches)	TREATMENT MEAN: Vine Weight (Gms.)
Filtrate A	6 lbs. 50% wp	22.7	91.3
Resuspended residue	6 lbs. 50% wp	3.5	9.5
Filtrate B	6 lbs. 100%	24.8	95.0
DDT w.p.	6 lbs. 50% wp	3.3	7.2
Check		21.2	86.0

comparison with filtrate A. Filtrate B represents the filtrate from 6 pounds of a 100 per cent technical DDT in 100 gallons of water. The technical material was ground in sand, which was then placed in water and agitated for 3 hours and then filtered three times through a No. 12 Whatman filter paper. These treatments were applied in the greenhouse to young Niagara cucumber plants just showing their first true leaves.

As shown in table 2, neither filtrate had a detrimental effect on the growth of the plants, but the resuspended residue and an original unfiltered spray suspension representing 6 pounds of a 50 per cent DDT wettable powder in 100 gallons of water caused severe stunting of the plants. This eliminated the possibility of any water soluble component fraction being the cause of phytotoxicity. From this it was evident that some non-water soluble component of the DDT was the cause of injury, and that this component was being adsorbed to such an extent by the charcoal, that the injury was lessened.

The work of Haller *et al.* (1945) showed that five compounds are the major constituents of technical DDT. Their approximate per cent composition of the technical material is as follows:

para para DDT	72.7%
ortho para DDT	19.0%
para para DDD	4.0%
2-Trichloro-l-o-chlorophenylethyl p-chlorobenzenesulfonate	1.85%
Dichloro diphenyl sulfone	0.6%

The op′ DDT was supplied by the Geigy Company Inc. The pp′ DDT was optained by repeated recrystallizations of the technical material from ethyl alcohol. The other three compounds were synthesized in the laboratory in sufficient quantity to carry out these tests. In addition to these compounds, a dehydrohalogenated DDT or DDE was also used.

Table 3.—Tolerance of Niagara cucumbers to component compounds of technical DDT, Riverhead, New York, 1953.

Treatment	Treatment Mean	
	Weight (Grams)	Length (Inches)
pp′ DDT	4.44†	4.47†
op′ DDT	5.94†	5.12
pp′ DDD	10.31	6.50
Technical DDT	3.31†	3.91†
Solvent check	7.81	5.37
Check	10.62	6.12
Dichloro diphenyl sulfone	10.37	6.25
2T l-o CpCS	8.12	6.50
DDE	5.25†	5.03*
L.S.D.	5%—0.63*	5%—0.28*
	1%—0.84†	1%—0.37†

This was obtained by refluxing the technical material in alcoholic KOH and subsequent recrystallization from ethyl alcohol.

The five component materials were applied in an emulsion spray at three times the concentration they are found in the technical material. An emusifiable concentrate was made for each compound on this basis. Each compound was dissolved in 4 cc. of acetone, to which 1½ cc. of *Triton X-100* was added, the resulting concentrate then being added to 1 pint of water. A Smith Streamline Blizzard Continuous Sprayer was used to apply the material to young Niagara cucumber plants in the greenhouse, each pot receiving approximately 5 cc. of spray material. This quantity proved sufficient to thoroughly wet the plants without causing any runoff. In addition to the five compounds mentioned, DDE and technical DDT were also used. These were applied in an emulsion spray, equivalent to 3 pounds actual technical DDT per 100 gallons of water in the same manner as for the other compounds.

Criteria for phytotoxicity were measured by the weight of the plants in grams, and by the length of the plants in inches from the growing point to the stem at soil level. These measurements were taken 25 days from the time of treatment. This test was repeated three times with equivalent results.

Significant differences shown in table 3 are measured from the solvent check, as the solvent had a depressing effect on the growth of the plants. 2-Trichloro-1-o-chlorophenylethyl p-chlorobenzenesul fonate has been shortened to 2T 1-o CpCS in table 3.

Technical DDT caused very severe injury to the plants, the growth being significantly poorer than any other treatment. The 19 per cent of the op′ DDT retarded growth almost as much as the 73 per cent of the pp′ DDT. DDE also reduced growth significantly from the solvent check, indicating that dehydrohalogenation of DDT does not alter the phytotoxic characteristic. The other compounds appeared to have no phytotoxic effect to the plants when applied at the rate present in 3 pounds of technical DDT.

Summary.—In general it appears that Niagara cucumbers are retarded as much by the 19 per cent of op′ DDT present in 3 pounds of technical material as by the 73 per cent pp′ DDT that it contains. pp′ DDD, dichloro diphenyl sulfone, and 2T 1-o CpCS when applied at the rate present in 3 pounds of technical material appeared to have no retarding effect upon the growth of the plants.

This would seem to indicate that DDT phytoxicity to Niagara cucumbers is primarily associated with the pp′ and op′ isomers of DDT.

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Response of Insects to Black and White Light[1]

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These experiments are a continuation of those reported in 1953[2]. Two Minnesota traps of similar construction were operated at State College during the summer of 1953. The traps were hung 8 feet above the ground and were controlled by a time switch which turned them on and off simultaneously. The operation period varied from 8:30 or 9 P.M. to 4:30 or 5 A.M., depending upon the intensity of the daylight at various periods of the summer In the first test, conducted from May 11 to July 16, the traps were separated by a distance of 100 feet with intervening foliage so that one light was not visible from the other. In the remaining tests the traps were hung adjacent to each other so that the lamp of one was 3 feet from that of the other. The collection and separation of the material was conducted as in 1952, that is, all the insects were identified to Order, Family and when desirable to Genus and Species. Identification to species was necessary in the case of insects such as the codling moth, the European corn borer and the elm leaf beetle.

A 100 watt BH 4 General Electric lamp with a red-purple filter emitting considerable invisible ultra violet light between 3000 and 3800 Ångstroms, was compared in all the tests with white frosted filament lamps varying from 10 to 100 watts. In speaking of the wattage of lamps in this paper reference is made to the input, as is the general practice, not the output. As in 1952, the BH 4 lamp is referred to as black light and the filament lamp, as white light. The spectral energy distribution of the BH 4 lamp is given in the results of the tests of 1952.[2] This lamp with the red-purple filter which was used in these experiments as well as those of 1952 emits less than 1 watt. The 10-watt white filament lamp emits approximately the same. The intensity of the BH 4 lamp in foot-candles is approximately the same as that of a 10-watt white filament lamp. The comparisons were made chiefly on this basis.

Table 1 summarizes the catches for 1953. In studying these results it should be remembered that certain insects are seasonal, they fly at different periods of the summer and therefore catches during May and June cannot be compared directly with those of July and August. It should also be noted that the traps were operated in the borough of State College where some insects such as the European corn borer and the cucumber beetles are not as abundant as they are in open areas. Although the temperature, precipitation and wind velocity varied throughout the summer, all the tests were conducted in the same locality and these factors can be eliminated as variables. The position of the light traps, that is whether operated apart or together, yielded quite different results. It is evident that larger proportional catches occur when lights of equal intensity are operated separately.

In drawing conclusions concerning the effectiveness of black and white light, careful comparisons should be made between the figures obtained in 1952 and those secured in 1953. During 1952, 100-watt black light and 100-watt white light were operated separately. During 1953, they were operated together.

To condense the material in the table, insects that did not come freely to the lights are combined under the heading "Other insects" for those particular

[1] Authorized for publication on October 31, 1953 as paper No. 1835 in the Journal series of The Pennsylvanian Agricultural Experiment Station.
[2] JOUR. ECON. ENT. 46(2): 376–7. 1953.

Table 1.—Insect catches from black and white light, 1953.

	5/11–7/16		7/17–7/25		7/27–8/5		8/6–8/16		8/18–9/2	
	Apart		Together							
INSECTS	100W BH 4	10W White	100W BH 4	10W White	100W BH 4	25W White	100W BH 4	50W White	100W BH 4	100W White
Culicidae	40	1	19	0	5	0	7	3	30	26
Anthomyiidae	183	12	21	0	32	0	10	0	22	12
Empididae	376	2	0	0	0	0	0	0	0	0
Borboridae	520	10	60	0	69	0	64	3	34	5
Tipulidae	71	7	11	0	37	3	27	6	88	22
Drosophilidae	3,870	41	191	2	234	4	115	7	188	68
Lonchopteridae	66	1	29	0	199	2	213	4	93	12
Agromyzidae	97	1	6	0	51	0	11	2	26	0
Phoridae	0	0	23	0	44	1	26	0	10	1
Midges	12,283	1,513	3,949	21	4,584	109	2,374	264	8,105	1,561
Other Diptera	264	19	30	1	69	6	33	5	30	18
Total Diptera	17,770	1,607	4,339	23	5,324	125	2,880	294	8,626	1,725
Carabidae	255	66	65	2	54	16	42	15	64	24
Staphylinidae	975	14	76	0	89	4	47	8	121	35
Scolytidae	52	6	14	0	10	0	2	1	10	3
Lampyridae	23	55	24	6	4	8	1	5	0	1
Elateridae	41	36	5	2	6	2	1	0	1	0
Chrysomelidae	7	2	4	0	81	2	100	15	35	15
Phyllophaga	29	37	0	0	0	0	0	0	0	0
Misc. Scarabs	94	34	15	1	40	3	12	5	29	20
Other Coleop	490	194	283	11	1,026	124	324	96	409	115
Total Coleop	1,966	444	486	22	1,310	159	529	145	669	213
Micro Lepidop.	1,522	439	278	9	383	46	288	58	371	193
Noctuidae	292	160	20	6	15	5	5	2	51	70
Tortricidae	100	65	27	3	36	7	46	41	132	132
Codling Moth	18	0	6	0	45	2	40	6	14	2
Crambidae	435	298	301	6	661	131	1,026	332	823	674
Other Lepidop.	372	349	135	12	78	35	64	57	93	91
Total Lepidop.	2,739	1,311	767	36	1,218	226	1,469	496	1,484	1,162
Aphididae	68	4	7	0	10	3	29	6	43	52
Cicadellidae	5,483	1,112	4,436	61	4,795	935	1,067	326	1,991	1,111
Miridae	146	174	34	3	49	59	69	88	188	295
Chrysopidae	7	88	4	0	11	3	14	5	9	3
Psocidae	20	26	13	0	21	11	22	14	37	37
Trichoptera	1,012	35	73	1	337	25	153	18	149	37
Ephemerida	9	1	0	0	0	0	1	2	1	0
Hemerobiidae	5	6	2	0	5	0	4	1	10	5
Hymenoptera	272	42	191	3	122	7	184	47	177	113
Total Misc.	7,022	1,488	4,760	68	5,350	1,043	1,543	507	2,605	1,653
Total	29,497	4,850	10,352	149	13,202	1,553	6,421	1,442	13,384	4,753

groups. For example, only a very few European corn borer adults were trapped. These are, therefore, included under "Other Lepidoptera."

The Rhyphidae and Chloropidae, which were counted separately, are included under "other Diptera." The midges include the Ceratopogonidae, Cecidomyidae, Chironomidae, Psychodidae and Simuliidae. The large catches of Drosophilidae which were consistent is illuminating and may lend a clue for control.

The Carabidae are rather frequent visitors to lights, however, most of them are not pests of plants. Since only 22 specimens of *Clivinia impressifrons*, an interesting species of some economic importance in corn areas, were taken, they are included with the Carabidae.

The Chrysomelidae include the spotted cucumber beetle, *Diabrotica undecimpunctata howardi*, the striped cucumber beetle, *Acalymma vittata*, and the elm leaf beetle, *Galerucella xanthomelana*. Only the latter came in sufficient numbers to warrant discussion. From July 27 to August 5, 78 specimens were taken at the black light and only two specimens at the white light. From August 6 to August 16, 92 specimens were taken at the black light and 50 specimens at the white light.

The Curculionidae, Bostrichiidae, Pselaphidae and an aquatic species *Berosus pantherinus* are included under "other Coleoptera." Thirty specimens of *Berosus pantherinus* were taken from July 6 to July 16, all from the black light.

"Other Lepidoptera" include small catches of the European corn borer, *Pyrausta nubilalis*, the grape leaf folder, *Desima funeralis*, the eastern tent tree caterpillar, *Malacosoma americana*, some Sphingidae, numerous Geometridae, Noctuidae not the cutworm class and others.

The catches of the diamondback moth,

Plutella maculipennis, were very small totalling only 109 from all tests. They are included with the Microlepidoptera.

The Noctuidae comprise the common cutworms, *Noctua c-nigrum*, *Feltia subgothica*, *Cirphis unipuncta*, and several species of *Autographa*. Each species was recorded separately.

The Tortricidae include numerous species. The most common are, *Archips rosaceana*, *Lapeyresia prunivorella* and *Sparganothis sulfureana*.

The Hymenoptera include ants and numerous parasitic species which were not identified.

It is very evident that more insects are generally attracted to black than to white light when the intensities in foot candles are approximately the same. If black and white lights of equal intensities are operated together the attraction is even more pronounced in favor of the black light. It therefore appears that black light traps might be used in the proximity of white lights to draw the insects away from them.

Diptera in general respond freely to black light. The Drosophilidae and the midges were especially noteworthy and in every case regardless of the position of the trap or the intensity of the lamp were more strongly attracted to the black light. The mosquito catches were not large enough to give significant comparisons. In 1952 black and white lights of equal wattage input attracted mosquitoes in approximately the same numbers indicating that if lights of equal intensities were used the catches at the black light would be greater. In 1953 the lights were compared on the basis of equal foot candles and the black light was far more attractive.

The majority of the Coleoptera do not respond to lights as freely as the Diptera. However, regardless of the intensity of the light or the position of the traps, they generally came more freely to the black light. The Phyllophaga and the Lampyridae may be exceptions. Unfortunately the Phyllophaga were not taken in sufficent numbers to draw satisfactory conclusions. It would appear that the black and white lights are equally attractive when oprated on the basis of equal foot candles. The Lampyridae seem to follow the same pattern.

Moths are known to respond freely to lights. In practically all cases more individuals came to black than to white light regardless of the intensity of the light or the position of the trap. The Microlepidoptera responded even more freely to black light than the Macrolepidoptera. This was evident in 1952 when 100-watt black light was compared with 100-watt white light operated separately. The figures for 1953 show the same trend even when lights of the same wattage were operated together.

The Noctuidae came more freely to black than to white light of the same intensities. White light of higher intensity, whether operated together or apart was more attractive.

The figures for codling moth, although small, show unquestionably that they are more freely attracted to black light. The same is generally true of all of the Tortricidae.

The Crambidae were attracted in large numbers to black light in 1953 regardless of the position of the traps or the intensity of the lights. When 100-watt black and 100-watt white lights were operated separately in 1952 the catches were approximately the same.

The aphid figures are too small to draw conclusions. Aphids are not nocturnal and only relatively small catches could be expected. It is possible that they were attracted at dusk or at dawn and were considerably affected by slight air currents in the vicinity of the traps, resulting in unreliable data. The few figures obtained indicate that they are probably attracted about equally to black and white light.

The Cicadellidae responded more freely to the black light under the conditions maintained during 1953. Larger catches were obtained from white light in 1952 when 100-watt black and 100-watt white lights were operated separately.

The Miridae no doubt responded more freely to the white light. This was pointed out in 1952 when 100-watt black and 100-watt white lights were operated separately. Larger catches were obtained in 1953 at white light of 25, 50 and 100-watt levels when the traps were operated together. However, a 10-watt white lamp caught less than a 100-watt black light when operated together.

The Trichoptera very definitely responded more freely to black light. This

was evident under all conditions during 1953 and bear out the conclusions reached in 1952. Separate counts were made of the Microtrichoptera (Hydroptilidae) which show the same trend.

Insufficient data is available for the Chrysopidae and Psocidae. Both seem to be more strongly attracted to white light.

The Hymenoptera are not generally recognized as night fliers however considerable numbers have been taken at lights. Under the conditions of 1953 they seem to be more strongly attracted to the black light.

SUMMARY.—In practically all cases the black light attracted more insects than the white light regardless of the position of the traps or the intensity of the lights. Exceptions occur chiefly in the Miridae and the Chrysopidae which apparently respond more freely to white light. The following table summarizes the results of the more outstanding groups.

The relative response of insects to black and white light

GROUP	BLACK LIGHT	WHITE LIGHT
Culicidae	moderate	slight
Drosophilidae	high	moderate
Other Diptera	high	moderate
Coleoptera	high	moderate
Microlepidoptera	high	slight
Noctuidae	high	slight
Tortricidae	moderate	moderate
Codling moth	moderate	slight
Crambidae	high	moderate
Other Lepidoptera	moderate	moderate
Cicadellidae	high	moderate
Miridae	moderate	moderate
Chrysopidae	slight	moderate
Trichoptera	high	slight
Hymenoptera	moderate	slight

Propagation of *Horogenes molestae*, an Asiatic Parasite of the Oriental Fruit Moth, on the Potato Tuberworm

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Horogenes molestae (Uchida), which was imported and extensively colonized from 1932 to 1937 (Allen *et al.* 1940), showed a far greater ability to attack the oriental fruit moth, *Grapholitha molesta* (Busck), than did any of the other 23 foreign parasites that have been colonized. Despite an initial high rate of increase at numerous colony locations, this species seems to have disappeared as a parasite of the oriental fruit moth in the United States.

During the early 1940's a great improvement was made in the propagation of the North American parasite *Macrocentrus ancylivorus* Rohwer through the use of the potato tuberworm, *Gnorimoschema operculella* (Zell.), as a breeding host, by a technique developed by the University of California and the California Agricultural Experiment Station (Flanders 1943) and (Finney *et al.* 1947), and along other lines by the Bureau of Entomology and Plant Quarantine at its laboratory at Moorestown, N. J. This parasite has been used extensively in mass liberations.

Because *Horogenes* had shown promise as an oriental fruit moth parasite, it was considered desirable to import it once more, to try to develop a better breeding technique on the tuberworm as a host. If this attempt proved to be successful, it was planned to use *Horogenes* as well as *Macrocentrus ancylivorus* in mass liberations. The tuberworm is more readily reared than the oriental fruit moth and can be propagated on potato, which is always readily obtainable. Rearing of the oriental fruit moth requires much more labor per unit of production, special lighting to prevent hibernation, and the use of small green apples that are reasonably free of fungi, worms, and poison residues, which cannot be obtained readily or in large quantities.

FIRST ATTEMPTS AT BREEDING ON TUBERWORMS.—In 1949 an opportunity to secure a breeding stock of *Horogenes* was presented when J. W. Ingram of the Bureau went to Japan on a special assign-

[1] E. L. Plasket assisted in these studies.

ment. He was able to arrange for K. Sato, formerly employed on the Bureau's oriental fruit moth investigations, to collect oriental fruit moth larvae from a section where this parasite was known to occur, and to ship the cocoons to Moorestown. From a shipment of several thousand cocoons received late in the summer, 45 females and 23 males of *Horogenes* were reared. These parasites were used in several successive exposures with the oriental fruit moth in sliced green apples, and with the tuberworm in potatoes. Enough progeny were obtained from the oriental fruit moth to continue the propagation.

The results with the first parasites exposed to tuberworms were discouraging. From September 2 to 19 five lots of tuberworms were exposed under excellent rearing conditions to *Horogenes* females emerging from the imported material. From these lots 3,116 tuberworm moths, 10 females and 4 males of *Horogenes* emerged. Although few parasites were bred from this host, they appeared normal. The propagating rate was so low that there seemed no prospect of increasing, or even of successfully maintaining the parasite on this host. Apparently the adult parasites did not oviposit freely in the tuberworms. For the 196 female-days of exposure to breeding parasites, the propagation was only 0.07 parasite per female-day, and the rate of parasitization only 0.4 per cent. In the best of these lots the propagation was 0.12 parasite per female-day and the parasitization 0.7 per cent.

BREEDING ON MIXTURE OF ORIENTAL FRUIT MOTHS AND TUBERWORMS.—Soon after the emergence of the F_1 generation of *Horogenes*, halves of green apples pinned to halves of potatoes along the cut surfaces were stocked with mixtures of oriental fruit moth and tuberworm eggs. Many of the newly hatched larvae of both host species entered at the junction of the cut surfaces, and during the first few days after entry were intermixed in this area. This method of presenting the hosts had the desired effect. *Horogenes* females immediately attacked the larvae along this junction, and parasitized the tuberworms at least as freely as they did the oriental fruit moths.

In the first test of this method, adults of the F_1 generation, obtained mainly from the oriental fruit moth, were used in seven successive exposures to fruit moths and tuberworms in apple-potato. In this test there were an estimated 90 female-days of exposure to the breeding parasites. The host mixture produced 2,993 unparasitized tuberworms, 136 unparasitized oriental fruit moths, and 212 *Horogenes* cocoons. Most of the cocoons were reared from the tuberworms. Of 25 host remains accompanying *Horogenes* cocoons that were examined microscopically, all were tuberworms. The 7.1 per cent parasitization and the production rate of 2.4 parasites per female-day showed that this method was successful as a means of stimulating the parasite to propagate in the tuberworm. In one check lot in which apple-potato halves were stocked with tuberworms but no oriental fruit moths were exposed to females of the F_1 generation, the parasitization was only 1.3 per cent.

During the winter of 1949–50 small-scale breeding of this parasite was continued through several generations on the tuberworm in mixture with the oriental fruit moth reared in the apple-potato halves. Several examinations showed that nearly all the parasites obtained from the mixture issued from the tuberworms. However, when the season arrived for increasing the propagation for mass liberations, the method was found to require too much labor for the results obtained. A change was made to spraying the tuberworm-infested potatoes with an ether extract of oriental fruit moth larvae.[2] A satisfactory rate of production followed.

During the following 4 months a large amount of work was done with extracts of the fruit moth applied to tuberworm-infested potatoes. Finally a technique was developed of rolling the infested potato, just before inoculation, in a mixture of finely ground apple that had been heavily infested with oriental fruit moths and ethyl alcohol.

In August a series of tests was set up in which there were check lots of tuberworms that had not been treated with any attractant. Parasitization by *Horogenes* in these checks was about as high as in any of the lots treated with attractants, providing the first evidence that a strain

[2] This change, suggested by M. H. Brunson, was made by W. P. Yetter, temporarily in charge of mass breeding.

suitable for breeding in the tuberworm had been segregated. This development had occurred in about 11 generations.

For several months after this discovery the routine breeding in tuberworms treated with alcoholic extracts of ground apple was continued, since it was suspected that the high parasitization observed in the no-attractant checks might be due to oriental fruit moth odors wafted into the inoculation cages either from breeding lots of that host or from attractants prepared from it that were present in the vicinity. However, in the summer of 1951 lots of tuberworm-infested potatoes not treated with fruit moth attractants were exposed to *Horogenes* in a section of the insectary free of any oriental fruit moth odors. The parasitization was as high as in similar lots reared close to the place where the fruit moths were reared, or to other lots treated with attractants. The use of attractants was then discontinued.

ROUTINE BREEDING ON TUBERWORMS.—At the end of 1952 *Horogenes* had been reared for more than a year on tuberworms not treated with attractants. It was concluded that, after a little more than 3 years and about 39 generations, a laboratory strain that can readily be propagated on the tuberworm had been developed. Although attractants were used in the early period of propagating it in the tuberworm, and they appear to have contributed to the rapid segregation of a strain that breeds freely on the tuberworm, such stimulation is no longer needed.

The propagating technique is as follows: All rearing is at 80° F. Tuberworm eggs are obtained on paper sheets, heated in hot water at 117° for 20 minutes to control *Nosema* disease, incubated for 2 days, and transferred to punctured potato at the rate of about 25,000 eggs to two 6-pound lots of B size in one breeding tray. As soon as hatching is completed and minute spots of frass begin to show, females of *Horogenes* are introduced and provided with honey on waxed-paper strips and drinking water in wet cotton. The parasites are kept in the trays for 3 to 4 days on racks in a walk-in breeding chamber, which is kept well lighted and moderately humidified (60 to 75 per cent). About 20 females are used per pound of potato, and since the parasites are productive over long periods, they are transferred from one tray of potatoes to another, as long as they remain vigorous. In each successive batch enough new parasites are added to maintain the desired number of breeding females per tray.

After exposure to parasites the tuberworm-infested potatoes in each tray are divided into two 6-pound lots. Each lot is provided with a bundle of corrugated-paper cocooning strips and sealed in a bag of unbleached muslin by means of paper staples overlaid with masking tape. The bags are spread out on racks in a low-humidity (35 to 50 per cent) walk-in breeding chamber in which the air is continuously and powerfully circulated and evacuated. As soon as the moths begin to emerge, the bags are opened and the cocooning strips and the spent potatoes, which are usually well stocked with parasite cocoons, are returned to the trays for the emergence period. The trays are returned to the moderately humidified breeding chambers. The cycle from the start of the incubation of the host eggs to the completion of parasite emergence takes about a month.

The technique is essentially the same as that used in the first lots reared without attractants. In 1952, 20 6-pound lots of tuberworm-infested potatoes were exposed to a total of 743 female parasites. The parasites reared from these females from June 1 to July 15 totaled 15,766, of which 5,101 or 32.4 per cent were females. The propagating rate per breeding female was 6.9 females. The number of parasites produced per pound of potato was 131 (42 females). Although this propagating rate is somewhat lower than that of *Macrocentrus ancylivorus*, which is propagated in the same manner, the technique is practicable. In 1952 there were 9,100 female-days of exposure to breeding parasites; hence the production was 1.7 adult parasites per female-day of exposure. This was 24 times the rate observed in the imported parasites, which were the first exposed to the tuberworm.

DISCUSSION.—The speed and ease with which *Horogenes molestae* has adapted itself to an alien host suggest that the method might be adapted to the propagation of other beneficial insects, or even that it might be used to assist in the acclimatization of an imported species. The segregation of this strain is similar in

most respects to the screening out of susceptible populations of strains resistant to insecticides. However, it differs in one way. It seems to depend on the development of an increased inheritance of a favorable behavior, the willingness to seek out and attack an unnatural host, whereas in strains resistant to insecticides there appears to be an inheritance of favorable physiological or anatomical characters. Since it has been shown in this species that a strain can be easily and quickly developed that has a behavior trait not previously well established but necessary for survival in the new environment, it seems possible that many beneficial species, in which initial attempts to colonize in a new area have not been successful, might eventually become established if a persistent effort were made to colonize and re-colonize with the progeny of partially acclimatized parents.

SUMMARY.—Although the parasite *Horogenes molestae* (Uchida) did not become established in the United States when colonized from 1932 to 1937, it was so effective in destroying larvae of the oriental fruit moth, *Grapholitha molesta* (Busck), immediately after liberation of moderate numbers, that it was reimported in 1949 for mass liberation experiments.

In the first attempt to rear it on the potato tuberworm, *Gnorimoschema operculella* (Zell.), the propagating rate was much too low for practical use. However, it was induced to accept the tuberworm as a breeding host by offering the females halves of potatoes pinned to apple and stocked with a mixture of oriental fruit moths and tuberworms. Subsequently the same effect was produced by spraying or rolling potatoes infested with young tuberworms with extracts of the oriental fruit moth.

By midsummer of 1950, and after about 11 generations had been stimulated to accept the tuberworm as a host, there was some evidence that the parasite would accept this host without stimulation. This was definitely proved in 1951, and since then the parasite has been propagated continuously in the tuberworm without attractants. This method, in which infested potatoes are exposed for several days to breeding parasites and then bagged for rearing in strongly circulated air to the cocoon stage, is essentially the same as the one used in propagating *Macrocentrus ancylivorus* Rohwer.

In the routine mass rearing of tuberworms used without attractants in 1952, the propagating rate per breeding female was 6.9 females, and 131 (42 females) parasites were produced per pound of potato used. This rate was 24 times as great as that obtained in the first attempt to propagate in the tuberworm in 1949. A laboratory strain of *Horogenes molestae* that can be satisfactorily propagated on the tuberworm has been developed.

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Penetration of Various Packaging Films by Common Stored-Product Insects[1]

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Transparent film materials are being used increasingly in the packaging of dried fruits, nuts, candies, cereals, grains, meats, cheese, and other food products. Cellophane has been used as a packaging material for many years. Recently, a number of new products such as saran, pliofilm, and polyethylene have been finding a variety of uses.

The penetration of packaged foods by insects is an important consideration in choosing a material in which to seal products such as dried fruits or nut meats, which are attractive to insects. The ability of insects to penetrate such packages varies and depends upon the insect species, its life stage, the type of film used, the thickness of the material, whether single film or laminated, and the effect of creases, scratches, and folds on the material.

Essig *et al.* (1943), in an extensive study on the penetration of packaging material by insects, concluded, in part, the insects with a propensity for boring are apparently the best penetrators, that none of the commercially used metal-substitute packaging materials tested are strictly insect-proof, and that manufacturing techniques are needed which will produce uniform containers without roughened spots, creases or folds, or similar areas where insects penetrate most easily.

Early in the spring of 1952, the authors began a study of the relative resistance of various packaging films to some of the common stored-product insects. The following is a report on the results to date.

MATERIALS AND METHODS.—The insect species used in this study were the following: the granary weevil, *Sitophilus granarius* (L.); the rice weevil, *Sitophilus oryza* (L.); the lesser grain borer, *Rhyzopertha dominica* (F.); the cadelle, *Tenebroides mauritanicus* (L.); the saw-toothed grain beetle, *Oryzaephilus surinamensis* (L.); the confused flour beetle, *Tribolium confusum* Duv.; the drug-store beetle, *Stegobium paniceum* (L.); dermestid beetle, *Trogoderma sternale* Jayne; Mediterranean flour moth, *Ephestia kühniella* Zell.; Indian-meal moth, *Plodia interpunctella* (Hbn.); and the German cockroach, *Blattella germanica* (L.). These insects, with the exception of the cockroach, were reared in wide-mouthed 1-gallon glass jars in a room in which the temperature was maintained at 80° F. and 60 per cent relative humidity. The cockroaches were reared in 50-pound-capacity metal lard cans.

The various insect species were reared on the following culture media: the granary weevil, rice weevil, and lesser grain borer, on cleaned whole wheat; cadelle, on a mixture of whole-wheat flour and rolled oats; confused flour beetle, on a mixture of whole-wheat flour and bran; saw-toothed grain beetle on a mixture of rolled barley and raisins; drug-store beetle and the dermestid beetle, on a balanced dog food referred to as "kibble." The cockroaches were reared on a different type of dry dog food (Laboratory Chow) which is used in maintaining rat colonies. The lepidopterous moths *Ephestia* and *Plodia* spp. were reared on a mixture of whole-wheat flour and powdered milk.

Two methods of testing the different packaging films were used, namely, the "lard-can test" and the "cup test." In the lard-can tests, a large population of the insect to be tested was established in a 50-pound-capacity lard can having approximately 3 inches of the appropriate culture media in the bottom. In the lid there was a hole 4½ inches in diameter, covered with fine-mesh wire screen.

Packaging films to be tested were made up into bags 3 by 5 inches in size, which were filled with walnut meats and then sealed according to standard commercial practices. Bag tops that were hand-sealed were not always tight, and such tops were additionally sealed with cellophane tape. Two or three bags of each film type were placed in each lard can on top of the culture media and examined for insect

[1] This work was undertaken at the request of and in cooperation with the California Walnut Growers Association.
Paper No. 796, University of California Citrus Experiment Station, Riverside, California.

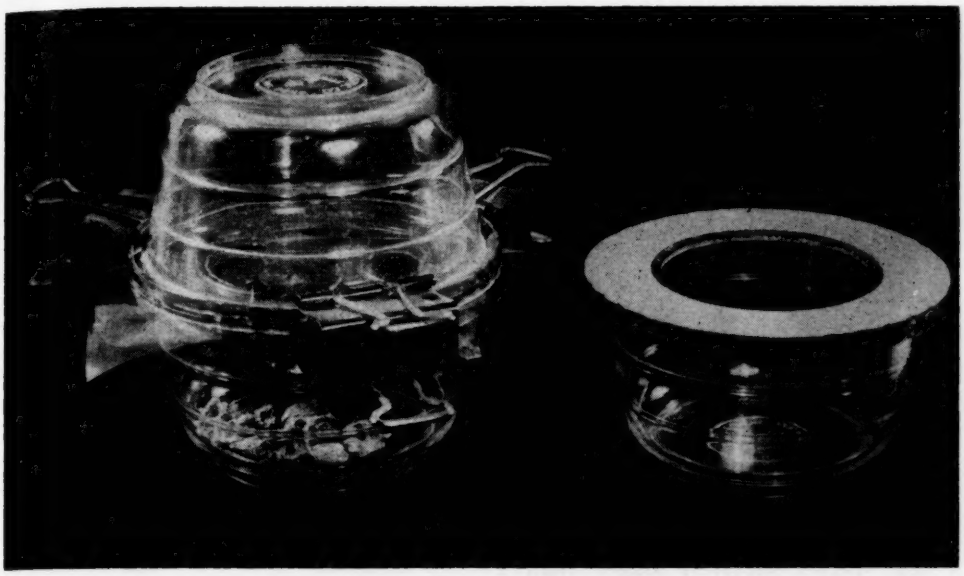

FIG. 1.—"Cup-test" apparatus in operation (left). One screw-top plastic cup (right) having a hole 2 inches in diameter in the top and containing 50 adult insects of the species to be tested was inverted over another containing appropriate food, with packaging film between, and the two were clamped together.

penetration at weekly intervals. The tests were usually terminated at the end of 8 weeks, but some were continued for 11 weeks. At the termination of a test a new series of cultures was started and the entire test was repeated.

Packages were considered to be penetrated only if the insect actually chewed through the film. If insects obtained access into the package through a small tear or through a poor seal, the package was discarded.

Packaging films used in these experiments were of five groups or types, as follows:

1. Cellophane:
   (a) 300 MST, 0.0009-inch thick
   (b) 450 MST, 0.0014-inch thick
   (c) 600 MST, 0.0016-inch thick
2. Polyethylene film:
   (a) 0.0015-inch thick
   (b) 0.002-inch thick
   (c) 0.004-inch thick
3. Saran film:
   (a) 0.0015-inch thick
   (b) 0.002-inch thick
4. Pliofilm, 0.0014-inch thick
5. Laminated film:
   (a) Tritect, 0.0029-inch thick (two layers of 300 MST cellophane, with a wax film between).
   (b) K-202, 0.0014-inch thick (450 MST cellophane, with saran coating 0.00005-inch thick on each side).
   (c) Saran (0.0015-inch thick) plus pliofilm (0.0012-inch thick).
   (d) Polyethylene (0.001-inch thick) plus aluminum foil (0.001-inch thick).
   (e) Pliofilm (0.0008-inch thick) plus aluminum foil (0.001-inch thick) plus acetate (0.001-inch thick).

In the laminated film packages, the thermoplastic materials such as cellophane, polyethylene, and pliofilm are generally on the inside, in order to heat-seal the closures.

The cup tests involved the use of two cups having screw-type plastic lids. A hole 2 inches in diameter was cut in the lid of each cup. A small amount of food was placed in one cup and 50 adult insects of the species being tested were placed in the other cup. A small piece of film was then placed over the lid of the first cup, and the second cup was inverted against the film. The two cups, with the film between, were held tightly together by three spring-type clips (Fig. 1). As the top surface of both cups had previously been ground flat, the lids and film fit tightly together and no insects could escape. The 50 insects in the top cup walked around on the film and either chewed through the film to reach the food or eventually died of starvation. The films were checked daily for insect penetration. In general, the length of time the insects lived in the absence of food determined the duration of the tests, which in

FIG. 2.—Cellophane (600 MST, 0.0016-inch thick) packages of walnut meats, showing penetration by larvae of the Indian-meal moth, *Plodia interpunctella* (Hbn.).

most cases was approximately a week, but a few species survived longer than 2 weeks.

RESULTS.—*Lard-Can Tests.*—More than 70 per cent of the cellophane packages used in these tests were penetrated by one or more stages of 10 species of insects tested, regardless of the thickness of the film (Table 1, Fig. 2). The saw-toothed grain beetle was the only insect of those tested that did not penetrate any of the cellophane packages. The granary weevil, dermestid beetle, cadelle, and lesser grain borer penetrated all the cellophane packages exposed to these insects, and the drug-store beetle, confused flour beetle, and German cockroach penetrated more than 80 per cent of the cellophane packages exposed to these insects.

Resistance of the polyethylene films to insect penetration increased with increase in thickness of the film. In these tests, the saw-toothed grain beetle and dermestid beetle were the only two insects that did not penetrate any of the polyethylene packages. The lesser grain borer and cadelle were the only species that penetrated the 0.004-inch-thick polyethylene packages. The 0.0015-inch-thick polyethylene package appeared to be more resistant to insect penetration than the 0.0016-inch-thick cellophane.

There was very little difference in insect penetration of the 0.0015-inch-thick and and the 0.002 inch-thick saran packaging films. The German cockroach, Mediterranean flour moth, and saw-toothed grain beetle did not penetrate any of the saran packages, but all the saran packages exposed to the lesser grain borer and cadelle were penetrated.

Packages made of pliofilm were similar to those of saran in their ability to resist penetration by the insects tested. The German cockroach, saw-toothed grain beetle, and confused flour beetle did not penetrate any of the pliofilm packages, whereas the lesser grain borer and the cadelle penetrated all the pliofilm packages.

Laminated film 5a, consisting of two layers of 0.0009-inch-thick cellophane with a wax film between, was more effective in resisting penetration than a single film of 0.0016-inch-thick cellophane, but 34.2 per cent of the packages were penetrated by the insects tested. All packages of this material were penetrated by the cadelle, lesser grain borer, and dermestid beetle; none were penetrated by the German cockroach, Mediterranean flour moth saw-toothed grain beetle, drug-store beetle, or confused flour beetle.

Laminated film 5b, consisting of cello-

Table 1.—Penetration of various packaging films by adults and larvae or nymphs of ten species of common stored-product insects in "lard-can tests."[1]

PACKAGING FILM	PERCENTAGE OF PACKAGES PENETRATED	AVERAGE NUMBER OF WEEKS REQUIRED FOR PENETRATION
Single-layer film:		
Cellophane		
300 MST, 0.0009-inch thick	76.5	3.0
450 MST, 0.0014-inch thick	73.7	3.0
600 MST, 0.0016-inch thick	78.4	3.8
Polyethylene		
0.0015-inch thick	60.5	2.9
0.002-inch thick	47.4	3.2
0.004-inch thick	13.1	3.0
Saran		
0.0015-inch thick	34.5	3.2
0.002-inch thick	35.1	3.9
Pliofilm, 0.0014-inch thick	37.3	5.5
Laminated film:		
Tritect, 0.0029-inch thick (two layers 300 MST cellophane with wax between)	34.2	2.8
K-202, 0.0014-inch thick (450 MST cellophane, with saran coating 0.00005-inch thick on each side)	55.3	3.8
Saran (0.0015-inch thick) plus pliofilm (0.0012-inch thick)	13.8	5.5
Polyethylene (0.001-inch thick) plus aluminum foil (0.001-inch thick)	8.1	4.3
Pliofilm (0.0008-inch thick) plus aluminum foil (0.001-inch thick) plus acetate (0.001-inch thick)	0.0	—

[1] Total of 506 tests. (For description of "lard-can tests," see "Materials and Methods.")

phane 0.0014 inch thick with a saran coating 0.00005-inch thick on each side was somewhat better than the 0.0014-inch-thick cellophane alone, but over 50 per cent of these packages were penetrated. All insect species tested penetrated one or more packages of this material.

Laminated film 5c, consisting of saran (0.0015-inch) plus pliofilm (0.0012-inch) was relatively resistant to insect penetration. Only 13.8 per cent of the packages were penetrated by the insects tested, the lesser grain borer and the cadelle being the two insect species that penetrated this material. None of the other species of insects penetrated packages of this film; some insects chewed through the outer lamination but did not continue through the inner lamination. This particular set of experiments was continued for 11 weeks.

Of all the packaging material tested, the nontransparent aluminum foil laminations of either poleythylene or pliofilm appeared to be the ones most resistant to insect penetration. The cadelle penetrated all packages of laminated film 5d, consisting of polyethylene (0.001-inch thick) plus aluminum foil (0.001-inch thick), while the dermestid beetle penetrated only a single package of this lamination. None of the packages of laminated film 5e, consisting of pliofilm (0.0008-inch thick) plus aluminum foil (0.001-inch thick) plus acetate (0.001-inch thick) were penetrated by the insects tested.

The average time in weeks required for insect penetration of films was obtained by totaling the weeks required to penetrate each package and dividing by the total number of packages penetrated. The variation in penetration time was great, a given insect species varying as much as 6 to 7 weeks in time required to penetrate the same material in the same culture. The dermestid beetles, for instance, penetrated two packages of 0.0009-inch-thick cellophane during the first week of exposure, but the third package was not penetrated until the seventh week. The lesser grain borer penetrated all the cellophane packages, all the cellophane-saran laminations, and all the 0.0015-inch-thick polyethylene films during the first week of exposure. This insect penetrated 66.7 per cent of the saran-pliofilm laminated packages, but no penetrations were made in less than 4 weeks. The cadelle also penetrated the above-named films in a short time but in some cases required a week or two longer to effect penetration than did the lesser grain borer.

Table 2.—Ability of adults and larvae or nymphs of 10 insect species to penetrate 14 different packaging materials in "lard-can tests."

INSECTS	PERCENTAGE OF PACKAGES PENETRATED	AVERAGE NUMBER OF WEEKS REQUIRED FOR PENETRATION
Cadelle	75.0	1.7
Confused flour beetle	25.0	2.9
Dermestid beetle	50.0	3.1
Drug-store beetle	43.6	5.6
German cockroach	28.0	3.6
Granary weevil	42.8	4.9
Indian-meal moth	32.1	4.2
Lesser grain borer	82.4	2.3
Mediterranean flour moth	30.4	4.5
Saw-toothed grain beetle	1.8	3.0

The ability of the various insects tested to penetrate 14 different packaging materials is shown by the data in table 2. It is noted in this table that the saw-toothed grain beetle, a common stored-product insect, penetrated only 1.8 per cent of the packages exposed to it, while the lesser grain borer penetrated 82.4 per cent and the cadelle 75.0 per cent of the packages. The lesser grain borer penetrated some or all the packages of all materials except the aluminum-foil laminations. This insect also required less average time to penetrate the packages than did any of the other species tested. Those insects commonly found in warehouses, grocery stores, and households, such as the Indian-meal moth, Mediterranean flour moth, confused flour beetle, and drug-store beetle penetrated from 25 to 44 per cent of the packages consisting mostly of the cellophane and 0.0015-inch-thick polyethylene films.

Cup Tests.—Results of the cup-test method of determining the resistance of sheets of various packaging films to penetration by adult insects are shown in tables 3 and 4. These data tend to corroborate those obtained in the lard-can or package tests, although there are some differences, probably because adult insects, only, were used in the cup tests, whereas adults and larvae or nymphs were used in the package tests.

Table 3.—Penetration of various packaging films by adults of seven species of common stored-product insects in "cup tests."[1]

Packaging Film	Percentage of Film Sheets Penetrated	Average Number of Weeks Required for Penetration
Single-layer film:		
Cellophane		
300 MST, 0.0009-inch thick	40	2.3
450 MST, 0.0014-inch thick	40	2.3
600 MST, 0.0016-inch thick	40	2.7
Polyethylene		
0.0015-inch thick	40	6.2
0.002-inch thick	33.3	5.8
0.004-inch thick	0	—
Saran, 0.002-inch thick	5	12
Pliofilm, 0.0014-inch thick	25	9.2
Laminated film:		
Tritect, 0.0029-inch thick (two layers 300 MST cellophane with wax between)	33.3	4.4
K-202, 0.0014-inch thick (450 MST cellophane with saran coating 0.00005-inch thick on each side)	35.7	3.4
Polyethylene (0.001-inch thick) plus aluminum foil (0.001-inch thick)	0	—
Pliofilm (0.0008-inch thick) plus aluminum foil (0.001-inch thick) plus acetate (0.001-inch thick)	0	—

[1] For description of "cup tests," see "Materials and Methods."

Table 4.—Ability of adults of seven insect species to penetrate 12 different packaging films in "cup test."

Insects	Total Number of Films Scarified	Percentage of Films Penetrated	Average Number of Days Required for Penetration
Confused flour beetle	0	0	—
Dermestid beetle	1	0	—
Drug-store beetle	0	0	—
Granary weevil	3	53.8	4.9
Lesser grain borer	7	69.0	4.6
Rice weevil	8	53.8	4.6
Saw-toothed grain beetle	1	0	0

The cellophane films and the 0.0015-inch-thick polyethylene films were the ones most readily penetrated in the cup tests. These were followed, in increasing difficulty of penetration, by the laminated film 5b (450 MST cellophane with saran coating), the polyethylene film 2b (0.002-inch thick), and laminated film 5a (two layers of 300 MST cellophane with wax film between).

Results with pliofilm in the cup tests (25 per cent of the films penetrated) were similar to those in the lard-can tests (37.3 per cent of the packages penetrated); but with saran only 5 per cent of the films were penetrated in the cup tests, whereas 35.1 per cent of the packages were penetrated in the lard-can tests.

As shown in table 4, adults of the lesser grain borer penetrated 69 per cent of the films in the cup tests, while the granary and rice weevils both penetrated 53.8 per cent. These results compare favorably with those shown in table 2, in that the lesser grain borer penetrated 82.4 per cent of the packages exposed to it, and the granary weevil penetrated 42.8 per cent. This may indicate that the adults of these two species are the effective penetrators, since the data in table 2 include penetration by both larvae and adult insects. It will be noted, however, that none of the films in the cup tests were penetrated by adults of the drug-store beetle, dermestid beetle, or confused flour beetle (Table 4), whereas from 25 to 50 per cent of the packages in the lard-can tests were penetrated by these insects (Table 2). Indications are, therefore, that the larvae of these three species may be the more effective penetrators. Since adults of the Mediterranean flour moth and of the Indian-meal moth do not have chewing mouth parts, it is the larvae of those insects that do the penetrating.

SUMMARY.—The resistance of various packaging films to penetration by common stored-product insects was tested (1) in "lard-can tests" packages 3 by 5 inches, made of the different packaging films and filled with walnut meats, were exposed to cultures of large numbers of adults and larvae or nymphs of given insect species in 50-pound-capacity lard cans, and (2) in "cup tests" 50 adults of a given insect species were confined in a plastic cup inverted over another cup containing an appropriate food supply, the two cups separated by a flat piece of packaging film which must be penetrated if the insects were to survive.

In these two tests 14 different packaging films were used and 11 species of insects, including the cadelle, confused flour beetle, dermestid beetle, drug-store beetle, German cockroach, granary weevil, Indian-meal moth, lesser grain borer, Mediterranean flour moth, rice weevil, and saw-toothed grain beetle. The following results are reported:

Nontransparent laminated film containing aluminum foil as one of the laminae was relatively resistant to insect penetration but not insectproof.

Of the transparent laminated films

tested, that consisting of saran 0.0015-inch thick and pliofilm 0.0012-inch thick was the one most resistant to insect penetration.

Cellophane films, single and laminated, were readily penetrated by most insects tested.

The resistance of polyethylene film to insect penetration varied directly with film thickness.

Of the insects tested, the lesser grain borer and the cadelle appeared to be the best penetrators of packaging films; the saw-toothed grain beetle appeared to be the one least able to penetrate the materials tested.

The ability of some insect species to penetrate packaging materials depended upon the stage of the insect (adult, larvae, or nymph).

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Use of Parathion to Control Olive Scale

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Parathion is the insecticide that is now most widely used for control of olive scale, *Parlatoria oleae* (Colvée). A report on preliminary tests of parathion made in 1947 and 1948 has been given (Stafford 1949). Following is a review of experiments on chemical control of olive scale conducted the 4 years after the preliminary tests.

The seasonal history of this scale is an important consideration in chemical control. Briefly, the scales overwinter as adult females. On olives in the central valley of California egg-laying starts in late March and hatching begins in early May. A second generation starts hatching in the latter part of July. There is little overlapping of the various developmental stages in the first generation as compared with the second. There are few scales (if any) of a third generation. On deciduous fruit trees the scales begin to lay eggs in early March or in late February. Hatching may take place in March but the peak of the hatch on deciduous fruit trees occurs in April. In other words, the development of the olive scale in deciduous trees in the spring appears to be about 3 weeks earlier than on the olive trees.

METHODS.—Although the olive processor prefers fruit that bears no evidence of olive scale infestation, if the olives are not deformed by the scales, or if the dark color produced by the scale has not penetrated too deeply into the fruit, they may be accepted and processed into dark ripe olives. In field tests for scale control all olives bearing scale marks or scales which had not yet made marks were considered. Thus, the percentages of clean fruit reported here are lower than would have resulted if the same fruit samples had been graded commercially at the processing plants.

The influence of degree of initial infestation is great enough to obscure or even reverse the rank of control treatments differing but little in efficiency. In one experiment the percentage of clean olives at harvest in 1948 was compared with the percentage of clean olives at harvest in 1949 for a series of 20 trees sprayed in June 1949. The treatment was a spray containing parathion 25 per cent WP at 2.5 pounds per 100 gallons of water. The fruit averaged 76.6 per cent in 1948 and 91.9 per cent clean in 1949. The regression coefficient of the percentage clean fruit the harvest after treatment (1949) on the percentage clean fruit for the harvest before treatment (1948) was calculated to be 0.205. The correlation was highly significant. Subsequently, infestation data on olives for the harvest the year before treatment were obtained whenever possible and were used to determine the

Table 1.—Control of olive scale on olives by winter sprays.

Olive Variety and Location Materials per 100 Gallons	Per Cent Clean Fruit at Harvest
Ascolano; Lindsay	
Medium summer oil emuls., 2.5 gals.[1]	0.0
Medium summer oil emuls., 2.5 gals.; parathion 15% WP, 1 lb.[1]	69.0
Light-medium summer oil emuls., 2.5 gals.; parathion 15% WP, 1 lb.[1]	58.0
Light summer oil emuls., 2.5 gals., parathion 15% WP, 1 lb.[1]	59.0
Sevillano; Fresno	
Medium summer oils emuls., 2 gals.[2]	0.0
Medium summer oil emuls., 1 gal.; parathion 25% WP, 10 oz.[2]	5.2
Medium summer oil emuls., 1 gal.; parathion 25% WP, 20 oz.[2]	7.2
Medium summer oil emuls., 2 gals.; parathion 25% WP, 10 oz.[2]	9.8
Medium summer oil emuls., 2 gals., parathion 25% WP, 20 oz.[2]	12.2
Very light summer oil,[3] 3.5 gals.; parathion 25% WP, 10 oz.[4]	0.0
Very light summer oil,[3] 3.5 gals.; parathion 25% WP, 20 oz.[4]	0.7

[1] Applied February 16, 1949.
[2] Applied February 17, 1949.
[3] An emulsifiable experimental oil, XP-9 Shell Oil Company.
[4] Applied February 16, 1950.

efficacy of the experimental treatments.

On deciduous fruit trees the pre-treatment infestation was measured in November or December from new twig growth. Final checks of the effectiveness of the control were made in the November or December following the treatments and were taken in the same manner as the pre-treatment data. Scale counts were made without regard to mortality. After treatments were applied in the dormant season (January to March) or in the spring (April to May), the scales found on the current season's growth in Novermber or December could only have resulted from survivors of the treatments or from scales brought into the orchard after treatment. The latter was considered a negligible factor in well established infestations. The arrangement of plots so that each treatment had approximately the same average initial infestation eliminated some anomalies in results. The variances of replicate samples within treatments varied so widely, however, as to make statistical analyses of the counts impractical. Another estimate of the efficiency of control measures on smooth-skinned fruits such as apricots and plums was a count of scale marked fruit at harvest. Scale marks on apricots do not "cook out" during canning. Plums bearing four or more scale marks are not accepted at packing houses for fresh fruit shipment. The marks made by scales may be dark or light depending on the variety of fruit infested.

Unless otherwise noted, all sprays were applied with hand spray guns and standard orchard sprayers operating at from 450 to 500 p.s.i. Trees were sprayed to the point of run-off. The number of gallons of spray required per acre varied from 500 for young trees to about 1900 for very large trees. Many orchards required 1500 gallons per acre. In most tests single tree plots were replicated from two to five times.

CONTROL ON OLIVES.—A comparison

Table 2.—Effect of date of spraying on control of olive scale on olives.

Olive Variety and Location Materials per 100 Gallons	Date Sprayed (1949)	Per Cent Clean Fruit at Harvest
Sevillano; Fresno		
Medium summer oil emuls., 2 gals.; parathion 25% WP, 1.25 lbs.	Feb. 17	12.2
Medium summer oil emuls., 1.5 gals.; parathion 25% WP, 1 lb.	June 10	76.7
Manzanillo; Madera		
Parathion 25% WP, 2.5 lbs.	May 5–6	65.0
	June 7–9	82.0
SV No. 1 oil,[1] 1 gal.; parathion 25% WP, 10 oz.; BAS,[2] 8 oz.	May 5–6	82.5
	June 7–9	91.5
Ascolano; Lindsay		
Parathion 25% WP, 2.5 lbs.	June 3	89.0
	July 28	57.7
Very light oil,[3] 4 gals.	June 3	68.2
	June 21	1.2
	July 19	0.7
	Aug. 10	4.8
Very light oil,[3] 4 gals.; parathion 25% WP, 1 lb.	June 3	92.0
	July 28	70.0

[1] A light oil, 91.8 U.R., General Petroleum Corporation, tank-mix.
[2] Blood albumin spreader.
[3] A 75% emulsion of a very light, low U. R. oil.

of several winter spray treatments is given in table 1. The addition of parathion wettable powder to oil sprays increased the efficiency and effectiveness increased with increase in both oil and parathion concentration. No large differences in effectiveness of the oil-parathion combination were observed between light grade, light-medium grade, or medium grade summer oils.[1] The very light grade summer oil (an experimental product) was not as effective in combination with parathion as was a medium grade summer oil.

Several comparisons of spray treatments applied on different dates are given in table 2. The data confirm those obtained in 1948 which indicate early June as the best time to spray olives for olive scale control. This was true of the use of oil alone, parathion alone, or the oil-parathion combination spray. Probably, sprays applied in late May would be almost as effective as those applied in early June. Olives are most often in bloom in late May, however, and parathion sprays applied at that time would constitute a severe hazard to honey bees gathering olive pollen. Sprays applied before bloom were less effective than sprays applied immediately after bloom. Late July sprays of oil-parathion were fairly effective. A logical explanation for the lower effectiveness of early July sprays is the presence of mature adult females which are difficult to kill. Though a second generation of scales starts hatching on olives about mid July, the developmental stages of the insect overlap widely during the remainder of the summer and fall. This means that a large percentage of the scale population is in immature stages (and thus more susceptible to insecticides) in late July. This percentage is not so high as it is in early June, and control treatments applied in late July are thus not so effective as treatments applied in the earlier, more favorable control period.

Table 3 gives the results of sprays of several oil-parathion combinations as well as other insecticides when applied in early June. As in the case of winter spray treatments, a very light grade of spray oil did not increase the effectiveness of parathion as much as did the light, light-medium, or medium grades of spray oils. Kerosene added little or nothing to the effectiveness of parathion. Not listed in table 3 are several experimental sprays of chlorinted insecticides including DDT, TDE, toxaphene, chlordane, aldrin, and dieldrin, used alone and in combination with petroleum oil sprays. At the concentrations used, these treatments gave such poor control that the plots were retreated and no harvest data were taken.

In general, table 3 shows that parathion was more effective than EPN, Metacide, malathion, or sulfatepp. In most comparisons the organic phosphate insecticidies were more effective when combined with petroleum oil spray. This was especially true of wettable powders. Sprays containing parathion and petroleum oil were the most effective from the standpoint of concentration of organic phosphate insecticide used. The use of 1.5 pounds of 25 per cent wettable parathion powder plus 3 liquid ounces of deposit builder gave consistently good control.

Except for sprays applied in 1950, all malathion treatments caused injury to olive fruit. When applied in early June, malathion caused a scabbing of the fruit which made the olives unfit for pickling.

Some growers and operators believed at first that the fumigant effect of parathion was great enough to make spray coverage a matter of minor importance. In one experiment paper bags were closed over several bunches of twigs just before spraying with parathion. The bags were removed immediately after the foliage dried. The parathion spray was, as usual, very effective against all stages of the male scales. The fumigant effect was great enough to kill a great many immature male scales that had been enclosed in the bags so that not all the surviving females were mated. These females later showed all the signs previously noted (Stafford 1949) as typical of the un-mated condition—large, distorted shells, the appearance of all or part of the body outside of the shell, dark even purple color of the body. The control in the bagged twigs was inadequate since nearly all of the bagged fruit was infested at harvest.

Some results obtained by the use of blower-sprayer types of spray application are listed in table 4. The data indicate less effective control when the gallonage of spray is reduced even though the

[1] California Administrative Code. Title 3, Agriculture. Article 5, Spray Oils.

Table 3.—Control of olive scale on olives by early June sprays.

Olive Variety, Location, and Date Sprayed Materials per 100 Gallons	Per Cent Clean Fruit at Harvest	
	The Year Before Treatment	Following Treatment
Sevillano; Fresno, June 10, 1949		
Parathion 25% WP, 2.5 lbs.		40.0
Parathion 25% WP, 1.0 lb.; light-med. flow oil, 1.5 gals.		76.7
Manzanillo; Madera, June 7–9, 1949		
Parathion 25% WP, 2.5 lbs.	76.6	91.9
Parathion 25% WP, 10 oz.; kerosene, 0.5 gal.		46.4
Parathion 25% WP, 10 oz.; S.V. No. 1 oil[1] 1 gal.; BAS,[2] 4 oz.	77.5	91.5
EPN 300, 1 lb. 11 oz.	59.0	25.0
EPN 300, 0.5 lb.; S.V. No. 1 oil,[1] 1 gal.; BAS 4 oz.		77.0
ASP 47, 2 oz. Vatsol K,[3] 1 oz.; S.V. No. 1 oil, 1 gal.		63.0
S.V. No. 1 oil, 1 gal.; BAS,[2] 4 oz.		31.0
Cube root,[4] 12 oz.; kerosene, 3 gals.; BAS,[2] 2 oz.		1.0
Ascolano; Lindsay, June 3, 1949		
Parathion 25% WP, 2.5 lbs.		89.0
Parathion 25% WP, 1 lb.; medium flowable oil, 1 gal.		77.2
Very light oil,[5] 4 gals.		68.2
Medium flowable oil, 1.5 gals.		12.2
Ascolano; Lindsay, June 6, 1950		
Parathion 25% WP, 5 oz.; very light flowable oil,[6] 3 gals.	1.3	73.1
Parathion 25% WP, 1.5 lbs.; deposit builder[7] 3 liquid oz.	0.2	90.0
Sevillano; Lindsay, June 1–3, 1950		
Parathion 25% WP, 2.5 lbs.	38	100.0
Parathion 25% WP, 5 oz.; very light oil,[6] 3 gals.	26	81.5
Parathion 25% WP, 10 oz.; very light oil,[6] 3 gals.	22	98.5
Parathion 25% WP, 5 oz.; very light oil,[5] 3 gals.	40	58.5
Parathion 25% WP, 1 lb.; deposit builder,[7] 4 liq. oz.	19	95.0
Parathion 25% WP, 1.5 lbs.; deposit builder[7] 3 liquid oz.	29	96.5
Metacide 50%, EM, 1 qt.	57	98.0
Metacide 50%, EM, 4 oz.; very light oil,[5] 3 gals.	47	99.0
EPN 300, 2.5 lbs.	55	94.0
EPN 300, 10 oz.; very light oil,[5] 3 gals.	39	76.0
Malathion 50% EM, 1 qt.	59	95.5
Malathion 50% EM, 1 qt.; very light oil,[5] 2 gals.	14	74.0
Sevillano; Lindsay, June 5–6, 1951		
Parathion 25% WP, 1 lb.; light-medium oil, 1.5 gals.	0.5	88.7
Parathion 25% WP, 0.5 lb.; light-medium oil, 1.5 gals.	5.0	59.5
Parathion 25% WP, 1.5 lbs.; deposit builder[7] 3 liquid oz.	2.0	95.0
Metacide 50% EM, 1 qt.	2.0	82.0
Metacide 50% EM, 1 qt.; light-medium oil, 1.5 gals.	2.0	83.0
EPN 50% EM, 1 qt.	8.0	73.5
EPN 300, 1 lb.; lt-medium oil, 1.5 gals.	2.0	78.0
Malathion,[8] 50% EM, 1 qt.	7.0	68.0
Malathion 50% EM, 1 qt.; light-medium oil, 1.5 gals.	11.0	85.0
Malathion 50% EM, 3 qts.	26.0	90.0
Malathion 50% EM, 3 qts.; light-medium oil, 1.5 gals.	6.0	90.0
Malathion 25% WP, 5 lbs.	27.5	57.5
Malathion 25% WP, 5 lbs.; light-medium oil 1.5 gals.	9.0	91.5
Systox, 1 qt.	4.0	0.0

[1] A light oil, 91.8 U.R., tank-mix, General Petroleum Corporation.
[2] Blood albumin spreader.
[3] 30% sodium dioctyl sulfosuccinate.
[4] 6.7% rotenone.
[5] A 75% emulsion of a very light, low viscosity oil.
[6] An experimental emulsifiable spray oil, Shell Oil Company XP-9.
[7] Colloidal Products Co. Petroleum sulfonates, petroleum oil, and free and combined fatty acids.
[8] All sprays containing malathion injured young olive fruit in 1951.

amount of parathion and oil applied was not reduced, or reduced only slightly. In one experiment the blower-sprayer was driven past the trees four times and the spray was thus applied from four rather than the usual two sides of a tree. This method of application gave better control. Table 4 also shows one instance of a better control by hand application than by blower-sprayer application. Considerable improvement has been made in blower-sprayer equipment since these tests were

Table 4.—Control of olive scale on olives with sprays applied by blower-sprayers.

Olive Variety, Location, Date Sprayed Materials per 100 Gallons	Gallons of Spray per Tree	Per Cent Clean Fruit at Harvest	
		The Year Before Treatment	Following Treatment
Manzanillo olives; Lindsay, June 2, 1949[1]			
Parathion 25% WP, 4 lbs.	15.6	—	71.0
Parathion 25% WP, 2.4 lbs.	31.2	—	93.0
Parathion 25% WP, 2 lbs.; med-oil, 1.4 gals.	15.6	—	66.5
Parathion 25% WP, 1 lb.; med-oil, 1 gal.	31.2	—	88.2
Sevillano olives; Lindsay, June 8–9, 1950[2]			
Parathion 25% WP, 10 oz.; very light oil[3] 6.8 gals.	14.3	13.0	14.0
Parathion 25% WP, 5 oz.; very light oil[3] 3.2 gals.	31.2	11.0	14.0
Parathion 25% WP, 5 oz.; very light oil[3] 3 gals. (hand sprayed)	35.0	40.0	58.5
Manzanillo olives; Woodlake, June 16, 1950[4]			
Parathion 25% WP, 1 lb.; lt-med. oil, 1.5 gals.	31.0	—	97.3
Parathion 25% WP, 2 lbs.; lt.-med. oil, 3.0 gals.; Vatsol OT[5] 85%, 4.8 oz.	15.0	—	96.2

[1] Bean Speed Sprayer with oscillating vane. Trees sprayed from 2 sides. Trees per acre, 27. Gallons of spray required per acre by hand spraying, 840.
[2] Ryder blower-sprayer. Trees sprayed from 2 sides. Trees per acre, 48. Gallons of spray required per acre by hand spraying, 1500.
[3] A 75% emulsion of a very light, low U. R. oil.
[4] Ryder blower-sprayer. Trees sprayed from 4 sides. Trees per acre, 48. Gallons required per acre by hand spraying, 1500.
[5] Sodium dioctyl sulfosuccinate.

made. Perhaps control by these improved machines will compare more favorably with hand spray gun application.

Parathion dust of 2 per cent strength was shown to be of value in olive scale control when applied in the latter half of July (Table 5). Where the infestation was not too great, two applications of 2 per cent parathion dust in May gave good control. Parathion applied at this time would be very hazardous to bees, however. The last of May (immediately after bloom) and first part of June was the best period for control using two applications of 2 per cent parathion dust at 100 pounds per acre at each application. Sulfur in-

Table 5.—Control of olive scale on olives with parathion and EPN dusts.

Conditions of Treatment	Date Applied	Per Cent Clean Fruit at Harvest	
		The Year Before Treatment	Following Treatment
Sevillano olives, Fresno. Niagara high velocity orchard duster	*1950*		
Parathion 2%	May 12		
	May 24	58.3	97.8
Undusted		0.0	0.0
Manzanillo olives, Lindsay. Ryder power duster	*1950*		
Parathion 2%	May 24		
	July 22	75.0	96.0
Parathion 2%	May 24		
	June 15	19.0	99.0
Parathion 2%[1]	May 24	76.0	94.0
Parathion 2%	July 15		
	July 31	20.0	81.0
Manzanillo (M) and Sevillano (S) olives Lindsay. Ryder power duster	*1951*		
Parathion 2% (M)[1]	June 5	95.8	87.0
EPN 3% (M)[1]	June 6	95.0	78.2
Parathion 2% (S)	June 6		
	June 15	87.0	87.2
Parathion 2%+sulfur 80% (S)	June 6		
	June 15	87.6	93.4

[1] Dust applied at 200 pounds per acre; other applications made at 100 pounds per acre.

Table 6.—Control of olive scale on border row and second row of manzanillo olives. Lindsay, Calif. 1951.

Location in Orchard of Trees Sampled	Per Cent Dead Adult Female Scales	
	Before Treatment[1] August 27	After Treatment October 10
Border row	19.2	63.5
Second row	20.3	80.0

[1] 100 pounds per acre of 2 per cent parathion dust applied by fixed-wing airplane.

creased the effectiveness of the parathion dust. Unfortunately, sulfur also increased the hazard of plant injury. Some scalding of young olives was noted from a commercial treatment of parathion-sulfur dust when the temperature reached 100° F. soon after appliation. Table 6 illustrates one of the major difficulties of the use of parathion dust. Border rows have shown less control from parathion dusting than trees farther inside the orchard.

It has been shown that parathion may enter into the oil of the olive and that much of the insecticide in the olive is not destroyed by the pickling and canning processes. Since the oil content of the olive does not begin to increase rapidly until August (Hartmann 1949), the California State Bureau of Chemistry has ruled that parathion shall not be applied to olive fruit after the first of August. That this ruling provides an adequate safety margin is shown in table 7. In this table are given the amounts of parathion found in the flesh of olives sprayed with parathion on various dates after the first of August. The amounts are not corrected for the "apparent parathion" found in untreated olives. It should be noted that the "green ripe" pickling process (the mildest process) gives an increase in "apparent parathion" in unsprayed olives.

In 1949, many growers used parathion for the first time. Though scaly fruit could be easily found in many orchards following an oil-parathion spray in June, in most cases growers were pleased with the reduction in amount of spotted fruit

Table 7.—Amounts of parathion found in the flesh of olives.

Variety; Materials per 100 Gallons	Date		Pickling Process	Parathion (P.P.M.)
	Sprayed[1]	Harvested or Collected		
Mission olives		*1949*		
Parathion 25% WP, 2 lbs. medium flowable oil emulsion, 1.5 gals.	Aug. 26	Aug. 26	None	1.18[2]
	Aug. 26	Nov. 2	None	0.21
Untreated	—	Nov. 2	None	0.11
Parathion 25% WP, 2 lbs. medium flowable oil emulsion, 1.5 gals.	Aug. 26	Nov. 2	Green ripe	0.21
Untreated	—	Nov. 2	Green ripe	0.18
Nevadillo				
Parathion 25% WP, 2.5 lbs.	Sept. 1	Oct. 11	Green ripe	0.14
Sevillano				
Parathion 25% WP, 1 lb. light-medium flowable oil emulsion, 1.5 gals.	July 17	Nov. 10	None	0.025
Parathion 25% WP, 1 lb. light-medium flowable oil emulsion, 1.5 gals.	July 17	Nov. 10	Dark ripe	0.07
Manzanillo				
Parathion 25% WP, 2.5 lbs.	Sept. 1	Oct. 11	Green ripe	0.07
		1950		
Parathion 25% WP, 1 lb. light-medium flowable oil emulsion, 1.5 gals.	Aug. 25	Oct. 5	None	0.12
Parathion 25% WP, 1 lb. light-medium flowable oil emulsion, 1.5 gals.	Aug. 25	Oct. 5	Green ripe	0.49
Parathion 25% WP, 1 lb. light-medium flowable oil emulsion, 1.5 gals.	Sept. 5	Oct. 5	None	0.43
Parathion 25% WP, 1 lb. light-medium flowable oil emulsion, 1.5 gals.	Sept. 5	Oct. 5	Green ripe	0.53
Parathion 25% WP, 1 lb. light-medium flowable oil emulsion, 1.5 gals.	Sept. 12	Oct. 5	None	1.75
Parathion 25% WP, 1 lb. light-medium flowable oil emulsion, 1.5 gals.	Sept. 12	Oct. 5	Green ripe	1.04

[1] Trees sprayed to point of run-off.
[2] Surface residue only.

Table 8.—Control of olive scale on July Elberta peaches by sprays applied in January.

Materials per 100 Gallons[1]	Number of Scales[2] per Bud on New Growth		
	Before Treatment	After Treatment	Per Cent Reduction
Sprayed in 1949			
Dormant oil emuls., 3.5 gals., Elgetol 30, 1 qt.	—	1.4	—
Dormant oil emuls., 2 gals.; DNC in oil,[3] 2 gals.	—	1.4	—
Dormant oil emuls., 4 gals.; Toxaphene 40% WP, 4 lbs.	—	1.2	—
Sprayed in 1950			
Dormant oil emuls., 4 gals.	8.6	4.6	46.5
Dormant oil emuls., 4 gals., Parathion 25% WP, 1 lb.	9.6	1.9	80.2
Dormant oil emuls., 4 gals.; Parathion 25% WP, 2 lbs.	8.1	2.3	71.6
Dormant oil emuls., 3.5 gals.; Elgetol 30, 0.5 gal.	8.2	3.1	62.3[4]
Dormant oil emuls., 3.5 gals.; DNC[5] 40%, 18 oz.	11.5	7.7	24.3[4]
Sprayed in 1951			
Dormant oil emuls., 4 gals.	0.42	.12	71.4
Dormant oil emuls., 3 gals.; Parathion 25% WP, 1 lb.	.42	.15	64.3
Dormant oil emuls., 3 gals.; Parathion 25% WP, 2 lbs.	.41	.08	80.5
Dormant oil emuls., 3 gals.; EPN 300, 2 lbs.	.43	.30	30.2
Dormant oil emuls., 3 gals.; Metacide, 1.5 lbs.	.42	2.43	
Dormant oil emuls., 3.5 gals.; Egetol 30, 1 qt.	.44	2.11[4]	
Dormant oil emuls., 3 gals.; Malathion 32.5%, EM, 3 pts.	.42	3.15	
Malathion 32.5% EM, 1 gal.	.44	2.43	

[1] All sprays (with the exception of those containing DN materials) contained 6 lbs. of basic copper sulfate in addition to the materials listed.
[2] Counts made in November and December.
[3] DNC—dinitro ortho cresol 2.5% in oil. California Spray Chemical Corp.
[4] Caused severe injury.
[5] Dinitro ortho cresol 40% wettable powder.

at harvest. The spray now most widely used is 1 pound of 25 per cent parathion wettable powder and 1.5 gallons of light or light-medium grade of summer oil emulsion per 100 gallons of water applied in early June. In one orchard where this spray has been applied commercially for 4 years the per cent of clean fruit has increased from 61 in 1949 to more than 99.9 in 1952. Several olive growers prefer parathion dusting to spraying since the dust may be applied by airplane and the cost of preparing the orchard for movement of heavy ground equipment is thus avoided. Two applications of 2 per cent parathion dust at 100 pounds per acre per application may be somewhat cheaper than one spray if the trees are large and require many gallons of spray for thorough coverage. In general, commercial dusting has not given as good control of olive scale as commercial spraying.

Table 9.—Control of olive scale on plums by spring sprays

Variety and Location Materials per 100 Gallons	Per Cent Fruit with Four or More Scale Marks
Santa Rosa Plums, Kingsburg	
Parathion 25% WP, 20 oz.[1]	0.0
Parathion 25% WP, 20 oz.[2]	5.5
Parathion 25% WP, 40 oz.[1]	0.0
Parathion 25% WP, 40 oz.[2]	1.0
EPN 300, 16 oz.[1]	10.0
EPN 300, 16 oz.[2]	38.0
EPN 300, 32 oz.[1]	2.0
EPN 300, 32 oz.[2]	74.0
Duarte Plums, Madera[3]	
Parathion, 25% WP, 1 lb.	34.0
Parathion 25% WP, 2 lbs.	20.0
Malathion 32.5% EM, 3 qts.	6.0
Malathion 32.5% EM, 2 qts.	4.0
Malathion 32.5% EM, 3 pts.	20.0
Metacide, 2 pts.	4.0
Metacide, 3 pts.	0.0

[1] Applied April 27, 1949.
[2] Applied May 13, 1949.
[3] Sprayed April 16, 1951.

CONTROL ON DECIDUOUS FRUIT TREES.—Peaches and nectarines must receive a pre-bloom fungicide spray. This spray is often applied during the dormant season. The combining of the fungicide and scale control in one spray effects a considerable saving in pest control. Some varieties of peaches and nectarines are often injured by heavy dosages of dormant oil spray. To give adequate control light dormant oils must be used at higher concentration than the heavier dormant oils usually used. At the higher concentration required light oils may also cause injury. A toxicant which would permit the reduction of the oil dosage was sought. Dinitro insecticides increased the effectiveness of oil spray and had the additional advantage of controlling peach leaf curl.

Table 10.—Control of olive scale on July Elberta peaches by spring sprays.

Date Sprayed Treatment per 100 Gallons	Number of Scales per Bud on New Growth		
	Before Treatment	After Treatment	Per Cent Reduction
Sprayed May 4, 1949			
Parathion 25% WP, 1.5 lbs.	—	0.05	—
Parathion 25% WP, 1 lb.; SV No. 1[1] oil, 1 gal.; BAS,[2] 4 oz.	—	0.06	—
Sprayed May 1, 1950			
Parathion 25% WP, 2 lbs.	8.2	0.10	98.8
Parathion 25% WP, 1 lb.	8.1	0.20	97.5
Parathion 25% WP, 0.5 lb.; very light oil,[3] 2 gals.	8.5	0.40	95.3
Parathion 25% WP, 1 lb.; very light oil,[3] 2 gals.	9.2	0.40	95.7
Very light oil,[3] 2 gals.	8.8	9.80	—
Sprayed April 24, 1951			
Parathion 25% WP, 1 lb.; very light oil,[3] 1 gal.	.44	.04	90.7
EPN 300, 1 lb.; very light oil,[3] 1 gal.	.54	.05	90.7
Malathion 32.5% EM, 2.3 pts.; very light oil,[3] 1 gal.	.48	.13	72.9
Malathion 32.5% EM, 3 pts.	.51	.31	39.2
Untreated	.003	1.01	—

[1] A light oil, 91.8 U.R. General Petroleum Corp.
[2] Blood albumin spreader.
[3] An experimental emulsifiable oil—XP-9. Shell Oil Company.

Oil-dinitro sprays have sometimes been used with success but have caused severe injury in some years (Table 8). In dormant spray tests on July Elberta peaches (Table 8) the use of 2 pounds of 25 per cent parathion wettable powder permitted the reduction of dormant oil emulsion from 4 or 5 to 3 gallons per 100 gallons of water while increasing control. The addition of 6 pounds of fixed copper fungicide per 100 gallons of water to this spray did not lessen its effectiveness. This treatment also controls overwintering eggs of spider mites and overwintering peach twig borer larvae (Summers 1951).

The use of parathion in the spring has the disadvantage of interferring with fruit thinning. In order to avoid handling parathion sprayed fruit, the grower must either thin early (and perhaps increase the hazard of loss by late frosts), or spray after thinning at a less favorable time for scale control. Table 9 shows that sprays applied to Santa Rosa plums on May 5, 1949, were less effective than sprays applied April 27, 1949. On plums, if the scales remain on the fruit long enough before being killed, the mark caused by the scales may still be evident at harvest. Again, parathion sprays applied after thinning may not allow sufficient time for weathering before harvest in the case of very early varieties. Spring sprays applied to peaches and nectarines are, of course, in addition to fungicide sprays. It is unfortunate that spring sprays of parathion have so many disadvantages since they have consistently given the best control of olive scale on deciduous fruits (Table 10).

In contrast to dormant sprays, EPN and oil applied in the spring (Table 10) gave equal control to parathion and oil. Metacide caused scars on many plums where the spray dried slowly (Table 9). Plum leaves sprayed with Metacide showed holes similar in appearance to shot-hole disease. The emulsifiable malathion formulation used in the spring of 1952 showed a marking of plums. One proprietary emulsifiable parathion formulation also caused the same type of injury. Apparently, certain emulsifying agents may cause injury to young plums without regard to the insecticide used.

SUMMARY.—Some factors influencing the effectiveness of control measures against the olive scale on olives and on deciduous fruit trees are discussed.

Parathion was the most effective insecticide tested. Its effectiveness was increased by the use of petroleum oil spray provided the oil was not lighter than the light summer grade.

For olives, the first part of June was the most effective time for application of sprays. The next most effective time was late July, causing no residue problem. Spring sprays of parathion on deciduous fruit trees were more effective than dormant sprays but spring sprays constitute

a greater hazard to human health.

Malathion caused injury to young olive fruit. Certain emulsifiable concentrate formulations of organic phosphate insecticides caused injury to young plums.

The use of parathion permitted the reduction in dosage of dormant oil for deciduous fruit trees while increasing the control of olive scale and also controlling overwintering eggs of spider mites and overwintering peach twig borer larvae.

Thorough spray coverage of both olive and deciduous fruit trees was an important factor in control.

Two applications of 2 per cent parathion dust were generally not so effective as one spring spray of oil and parathion to control olive scale on olive trees.

Annual commercially applied sprays of parathion have greatly reduced the olive scale infestations. Failure to spray nearly always resulted in appreciable increases in scale infestation.

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Predatism of European Corn Borer Eggs by Arthropods[1]

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The literature contains a number of references to the destruction of European corn borer eggs by arthropod predators. Hergula (1930) reports that young of the mite *Trombidium fuliginosum* Koch destroyed 16 per cent of the eggs in fields under observation. Zwölfer (1928) also reports this species, and Paillot (1928) reports *Allthrombium fuligonsum* Herm., as feeding on corn borer eggs. Both Hergula and Paillot, as well as Everly (1938b) and Poos (1927), reported chrysopids feeding of the eggs. In addition, Zwölfer also reports the feeding of *Coccinella septempunctata* L., and Crawford & Spencer (1922), Caffrey & Worthley (1927), and Everly (1938a) all report the feeding of *Certomegilla fuscilabris* (Muls.) on corn borer eggs. However, no study has combined a complete record of the fate of a known number of eggs with a numerical census of the various predaceous species present. Accordingly, investigations were carried out at Lafayette, Indiana in 1946 to attempt to determine the proportion of eggs destroyed by predators and the species and numbers of predators present.

Four hybrid corn varieties were used. These were: attractive (L317×Tr) and unattractive (A×CC5) single crosses, and Indiana commercial hybrids 818 and 610B, attractive and unattractive double crosses respectively, as based on previous tests of inbred lines in the pedigree. These were planted in ten blocks, each a randomized Latin square. Each plot consisted of three hills, the corn being thinned to one plant per hill. Plantings were made on May 10 and 23 and June 18 at Lafayette and on May 15 and 23 at West Lafayette, Indiana. A third planting was not made at the latter location because soil conditions there did not favor late corn.

The first and second plantings were used for first generation studies and the second and third for second generation. Each block was examined for eggs and predators three times per week and observations recorded on an individual form for each hill. Each egg mass was encircled and numbered on the leaf with India ink when first found. Its number, location on the plant, date found, and number of eggs were recorded on the

[1] Contribution from the Department of Entomology, Purdue University, Lafayette, Indiana.

appropriate form. By utilizing this information, the mass could be located at each succeeding examination and any change in its status observed and recorded. The mass was observed until it hatched, disappeared, or was consumed by predators. No difficulty was experienced in distinguishing hatched and consumed eggs when a hand lens was used. All stages of predaceous arthropods seen were recorded on the form for that hill, with the date. In order not to remove predators, identification was made only to that level which could be determined in the field. Only *Orius insidiosus* (Say) nymphs and adults and coccinellid adults were readily identified to species. Each plant was measured to its extended height periodically and silking dates for each were recorded.

Actual observation of predatism was rare. Mites were twice seen feeding on eggs, and in another instance one was seen on an egg mass but was not feeding. Although nymphs and adults of *Orius insidiosus* were observed on or near egg masses several times, only one was seen feeding. One thrips nymph was seen on an egg mass, but was not feeding. In adjacent corn, Dr. H. O. Deay found an adult *C. fuscilabris* which had just eaten four eggs from a mass. Mr. R. T. Everly observed a larva of the same species feeding, also in an adjacent plot. After it finished feeding, examination of the mass revealed that 49 of the 52 eggs had been consumed. All of the common predators were seen feeding on aphids, and many were seen feeding on some stage of their own or other predaceous species.

FIRST GENERATION.—Table 1 gives details of these studies. A total of 9061 first generation eggs, or an average of 23.6 per plant, were found. Ind. 818 received the largest number of eggs per plant, both in the grand total for the generation and in all breakdowns of location and/or date. This strain received 37.1 eggs per plant, followed by Ind. 610B with 21, A×CC5 with 19.5 and L317×Tr with 16.9. Combining both locations, the first planting received 38.7 eggs per plant and the second planting 9.1. Combining planting dates, the corn planted at Lafayette received 31.6 eggs per plant compared with 15.6 on that at West Lafayette.

A total of 785, or 8.7 per cent, of the 9061 eggs were destroyed by predators. There seemed to be no correlation between strains, blocks, planting dates or locations and the per cent of eggs destroyed. As might be expected in a mobile population, there was no correlation between eggs destroyed and strain of corn.

Table 1.—First generation studies, showing average height of corn, number of eggs per plant, per cent eggs destroyed, and number of predators observed.

	Strains of Corn				
	A×CC5	Ind. 818	L317×Tr	Ind. 610B	Total or Average
		First Planting			
Lafayette					
Average height (inches)	26.1	27.1	22.5	26.5	25.6
Number eggs per plant	37.96	67.00	39.84	40.83	46.41
Per cent eggs destroyed	8.23	8.38	4.18	14.79	8.78
Number predators	20	10	17	10	57
West Lafayette					
Average height (inches)	29.7	30.3	25.9	27.6	28.4
Number eggs per plant	27.45	49.42	11.67	30.38	29.73
Per cent eggs destroyed	2.42	5.90	0.71	0.68	3.26
Number predators	40	27	16	30	113
		Second Planting			
Lafayette					
Average height (inches)	24.0	22.4	18.1	22.1	21.7
Number eggs per plant	11.38	27.92	16.04	12.13	16.87
Per cent eggs destroyed	28.20	21.79	4.15	19.58	17.73
Number predators	4	2	0	5	11
West Lafayette					
Average height (inches)	18.0	19.1	14.7	16.6	17.1
Number eggs per plant	1.00	4.04	0.00	0.50	1.39
Per cent eggs destroyed	0	0	0	0	0
Number predators	13	8	3	7	31

Within locations, however, the blocks which had the most eggs also had the most predators and usually had the highest percentage of eggs destroyed. The per cent of eggs destroyed at Lafayette (11.3) was more than three times that at West Lafayette (3.1), although less than one half as many predators were observed. There were more than twice as many eggs at Lafayette, which would probably tend to make them easier for the predators to locate.

The most abundant predator species was *Ceratomegilla fuscilabris*, 137 being seen. *Hippodamia convergens* Guer, was present in much smaller numbers, only 37 being seen, and there was a scattering of *Orius insidiosus*, mostly nymphs. Ladybird larvae, larval and adult lacewings, and *Hippodamia tredecim-punctata* (L.) adults were rather rare. Three or fewer of the following were found: *Coccinella novemnotata* Hbst., *Cycloneda sanguinea* (L.), *Adalia bipunctata* L., thrips, reduviids, nabids and mites. Predator populations on a per plant basis probably cannot give an accurate and completely significant picture of actual conditions. The picture may be distorted by movement of the predators, feeding at night or in the early hours of daylight, and the length of time (2 days) required to make a round of observations. Also, such a figure for the whole period when first generation eggs were present probably cannot be compared with eggs destroyed as it could not take into account the presence of eggs and predators on the same corn at different times.

At West Lafayette, 144 predators were observed during the time first generation eggs were present while only 68 were seen at Lafayette. In each location, more predators were seen on the first planting than on the second. Although there were more eggs on the first planting, comparative numbers of eggs and predators indicate this is not likely the only reason. At Lafayette, the first planting had less than three times as many eggs as the second, but more than five times as many predators. At West Lafayette, where there were fewer eggs and more predators, the first planting had more than 21 times as many eggs and slightly more than three times as many predators as the second. Within blocks, predators seemed well distributed, strain of corn, location of the plot in the block, and the number of eggs in the block apparently having no influence.

SECOND GENERATION.—Table 2 presents details of these studies. A total of 1009 eggs, or an average of 3.5 per plant, were laid on or before August 18. Since it was necessary to conclude observations on August 26, eggs laid after the 18th are not included. Fourteen masses containing 230 eggs were laid after that date. Of these, 39 had been eaten by predators,

Table 2.—Second generation studies, showing average height of corn, number of eggs per plant, per cent eggs destroyed, and number of predators observed.

	Strains of Corn				
	A×CC5	Ind. 818	L317×T4	Ind. 610B	Total or Average
	Second Planting				
Lafayette					
Average height (inches)	84.3	96.8	98.8	85.5	91.6
Number eggs per plant	1.63	6.84	1.38	0.84	1.17
Per cent eggs destroyed	66.67	0	0	0	23.21
Number predators	89	91	77	116	373
West Lafayette					
Average height (inches)	84.2	90.7	94.2	84.3	88.2
Number eggs per plant	0.00	5.58	8.29	6.58	5.22
Per cent eggs destroyed	0	0	73.37	75.00	54.29
Number predators	105	102	69	139	415
	Third Planting				
Lafayette					
Average height (inches)	76.2	79.1	75.5	75.2	76.4
Number eggs per plant	1.29	3.92	7.67	3.63	4.13
Per cent eggs destroyed	0	35.01	18.48	18.39	20.96
Number predators	246	106	130	175	657

64 had disappeared, 26 had hatched, and 101 were still on the plants in good condition when observations were halted.

L317×Tr received the highest number of eggs per plant for the generation (5.8) and in all combinations of location and/or date. It also received the highest average number of eggs per plant in five of the six blocks. Ind. 610B received 3.7 eggs per plant; Ind. 818, 3.45; and A×CC5, 0.97. The third planting (Lafayette, June 18) received a slightly higher number of eggs per plant (4.1) than the second planting (both locations. May 23), which received 3.2. At Lafayette, the third planting of every strain received more eggs per plant than the second, with all except A×CC5 receiving at least four times as many.

A total of 381, or 37.8 per cent, of the 1009 second generation eggs were destroyed by predators. Strains, blocks, and planting dates seemed to have no consistent influence on the per cent of eggs destroyed. The second planting had a much higher (47) per cent of eggs destroyed than the third (21); however, this reflects a high (54.3) per cent destroyed on the second planting at West Lafayette where there was no third planting. At Lafayette, 23.2 per cent of the eggs on the second planting and 21 per cent of those on the third were destroyed. The fact that the percentage of eggs destroyed at West Lafayette was more than twice that at Lafayette is probably accounted for by the greater concentration of eggs, there being 501 eggs on two blocks of corn at West Lafayette and 508 on four blocks at Lafayette.

Although *Ceratomegilla fuscilabris* was again the predator seen in greatest numbers, several others had increased in much greater proportion since the first generation observation period. A total of 530 *C. fuscilabris* were seen, as were 304 *Hippodamia convergens*, 62 ladybird larvae, and 162 lacewing adults and 44 larvae. *Hippodamia tredecim-punctata* was abundant at Lafayette where 164 were seen, but only two were seen at West Lafayette. Other predators observed often were: 55 *Coccinella novemnotata*, 50 *Cycloneda sanguinea*, 46 *Hippodamia parenthesis* Say, and 25 adults and two nymphs of *Orius insidiosus*. Three nabids, two pentatomids, and two adults of *Adalia bipunctata* were also seen.

While the presence of eggs on certain strains of corn appeared to have no influence on the number of predators observed there, the presence of unusually large numbers of aphids on certain plants tended to be accompanied by an increase in the number of predators, especially *Hippodamia tredecim-punctata*, on those plants. Thus a strain of corn which was uniformly and highly attractive to aphids probably would have large numbers of certain predators. In this study, however, the two strains (Ind. 610B and Ind. 818) which most often had plants heavily infested with aphids ranked second and fourth, respectively, in total predators observed during the second generation.

A×CC5, which had the fewest eggs, had the most predators. At Lafayette, the most predators were found on the third planting, which also had the most eggs. However, more than one third of the predators on that planting were on A×CC5, which received no eggs. Irrespective of planting date, the number of predators per plant was about the same at the two locations, there being about two and one-half times as many predators on the four blocks of corn at Lafayette as on the two blocks at West Lafayette.

SUMMARY.—Four strains of corn, two attractive and two unattractive to European corn borer moths, were planted in ten blocks, each a randomized four by four Latin square. Two blocks were planted on each of three dates at Lafayette and each of two dates at West Lafayette, Indiana. The first two plantings were used for first generation studies, and the second and third for second generation studies. Each block was examined for eggs and predators thrice weekly and a record kept of each egg mass until it hatched, disappeared, or was destroyed by predators.

Of the 10,076 eggs laid during the season, 1166, or 11.6 per cent, were destroyed by predators. The first generation combined a large number of eggs (9061), a small number of predators (212), and a large number (785) but small per cent (8.7) of eggs destroyed. In the second generation a small number of eggs (1009) was combined with a large number of predators (1445) and a small number (381) but high per cent (37.8) of eggs destroyed. Thus it appears that in years when there is a large second generation of the European corn borer, predators

might destroy a considerable number of eggs.

Actual observation of predatism in the plots was rare, mites and *Orius insidiosus* being the only predators seen feeding. Both a larva and an adult of *Ceratomegilla fuscilabris* (Muls.) were seen feeding on eggs in adjacent corn by other observers. These observations, coupled with the fact that it was the most common predator species during both of the periods when eggs were present, indicate that it was the most important predator present.

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European Pine Shoot Moth Control Tests

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In 1951 and 1952 the New York State Science Service in cooperation with the New York State Conservation Department carried out a series of experiments for the control of European pine shoot moth, *Rhyacionia buoliana* (Schiff.) on red pine by airplane spraying. The experimental areas chosen for the work are located in south central New York in state reforestation areas of Madison and Chenango Counties where considerable damage by the insect has been experienced.

Experiments by other workers have shown that considerable reduction in damage by this insect may be obtained by the proper application of insecticides using hydraulic ground equipment. Hamilton (1931) found that a mixture of nicotine sulphate and *Penetrol* killed the adult moths and eggs. Glasgow & Van Buren (*ca.* 1934) and Friend & Plumb (1938) found both lead arsenate and rotenone to be effective against the newly hatched larvae. More recent work has shown DDT to have a long lasting effect against newly hatched larvae (Friend & Plumb 1952, Stearns 1953).

The use of hydraulic ground equipment is limited to small plantings of trees and is impractical in large reforestation areas where the labor and expense involved would not be justified. Therefore, studies on the control of the European pine shoot moth by airplane spraying were made. DDT at various concentrations per acre was sprayed at the time the moths were emerging and laying eggs. Results of these tests are presented in this paper.

MATERIALS AND METHODS.—In *1951*, four plots were selected for the experiments. Three are located in Madison County within a quarter of a mile of each other in what is referred to here as the spray area. The fourth plot is located in Chenango County within a few miles of the spray area and is referred to here as the check area. The DDT concentrations used are given in table 2.

Prior to spraying, observations were made on the plots to determine the stages

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Table 1.—Correlation of height of trees with intensity of attack by the European pine shoot moth in the experimental areas in 1951.

Height Class in Feet	Check Area		Sprayed Area	
	Number of Trees	Per Cent Damaged Tips	Number of Trees	Per Cent Damaged Tips
6– 8	12	42	20	46
8–10	13	43	28	41
10–12	42	39	23	33
12–14	26	41	5	42
14–16	6	18	0	0
Totals	99		76	

of the moths. By July 10 pupae, emerged adults, eggs and newly hatched larvae were found on the trees. Observations of numerous damaged buds and puparia indicated that most of the moths had already emerged.

Spray applications by airplane were begun on July 11 and completed on July 12. The airplane used for the applications was a Stearman biplane, owned by the New York State Conservation Department, which was equipped with 42 B-5 Spraying Systems nozzles mounted on a 30-foot boom on the lower wing. This equipment was calibrated to deliver 2 gallons of spray per acre at a nozzle pressure of 70 p.s.i. when the plane is flown at 80 m.p.h. air speed at about 100 feet elevation. The DDT used was formulated by dissolving technical grade DDT in *Sovacide PD 544B* at the rate of 3 pounds in 3 quarts of solvent. To this was added 5 ounces of *Triton X-100* emulsifier. This made 1 gallon of concentrate which when mixed with 2 gallons of water gave 3 gallons of finished spray with 1 pound of DDT per gallon.

Sprays were applied in morning and evening hours when air currents were at their minimum. Several 4″×6″ glass plates placed on the ground in open spaces in the plots indicated there was a good deposit of spray. Since the airplane equipment was calibrated to deliver 2 pounds of DDT in 2 gallons of spray per acre it was necessary to make a second application to Plot 3 so that its treatment was actually 2 pounds DDT in 2 gallons of spray per acre applied twice, rather than 4 pounds DDT in 4 gallons of spray per acre applied once. In Plot 2 which received 3 pounds DDT in 3 gallons of spray per acre, one application was made at the rate of 2 gallons per acre and a second application was made with half the spray nozzles plugged so that the delivery was 1 gallon per acre. Since all spraying was done under good conditions for airplane spraying, it is felt that the spray deposit was the best that could be obtained.

In October 1951, data were collected on the experimental plots for the purpose of evaluating the effects of the sprays. The method used provided for the examination of 10 red pine tips for damage on each tree chosen for sampling. The tips were picked at random at about breast height. In order to determine the size limit of trees to be used for sampling, a number of trees of various heights were sampled in the experimental areas by the method described. Table 1 presents the data collected by height classes. It will be noted from it that trees from 6 to 14 feet high were attacked with equal intensity. Therefore, trees chosen for measuring the effects of the spray were selected within these limits. The number of trees selected for sampling on each plot depended to a large extent on the size of the plot. In order to insure an even distribution of the sample trees, the plots were divided into sections and sample trees were picked at random in the sections, making sure that the trees were evenly distributed within each section.

The method of determining damaged tips was based on conditions as they were found in the field at the time of observation. In the fall, new damage on tips was determined by the finding of a pitch mass in the new bud cluster. Older damage was determined by deformities or lack of lateral shoot growth for a particular year. In the spring, after growth had started, damaged tips could be detected by dead or injured buds or deformed new shoots.

In 1952 the tests were carried out in the same general areas as in 1951. The plots were sprayed with 4 pounds of DDT per acre. The main objective was to confirm results obtained in 1951. Therefore, three replicate plots were sprayed on July 10 and 11, 1952 using the same DDT formulation and equipment as in 1951. At the time of spraying, most of the moths had emerged and were laying eggs. Some of the eggs had already hatched and it appeared that although the same conditions prevailed on the same dates in 1951, yet there seemed to be a greater percentage of adult emergence in 1952. At the time of

these observations a pre-spray count was made of damaged tips on the plots. Post-spray counts were made in November 1952 by examining the new bud clusters.

RESULTS.—Results of tests in 1951 and 1952 are presented in table 2. It may be seen that in 1951 2 pounds of DDT and 3 pounds of DDT per acre respectively, had no effect in reducing damage by the moth. Four pounds of DDT per acre reduced damage to 12 per cent. By Abbott's formula the reduction is 69 per cent. Follow-up counts of damaged tips in this plot in November 1952 indicated that damage had gone to 34 per cent, which is practically the same as it was before spraying. Data from the 1952 experiments show that no appreciable reduction in damage was obtained with 4 pounds DDT per acre in any of the replicates.

Table 2.—Red pine tips damaged before and after spraying with DDT for control of the European pine shoot moth.

Plot No.	No. of Acres	DDT spray per Acre	Before Spraying Total Counted	Before Spraying Per Cent Damaged	After Spraying Total Counted	After Spraying Per Cent Damaged
Sprays applied—July 11 & 12, 1951						
1	25	2 lbs. in 2 gallons	500	31	500	39
2	6	3 lbs. in 3 gallons	250	34	250	47
3	60	4 lbs. in 4 gallons	990	38	990	12
4	45	None	750	44	990	39
Sprays applied—July 10 & 11, 1952						
5	20	4 lbs. in 4 gallons	1000	63	100	56
6	20	4 lbs. in 4 gallons	1000	31	1000	30
7	20	4 lbs. in 4 gallons	1000	19[1]	1000	35
8	12	None	600	45	600	46

[1] Because of rain and wet foliage at time of counting, this count is not representative of the entire plot.

DISCUSSION.—No satisfactory explanation was found to account for the fact that appreciable reduction in damage occurred with the four pounds of DDT in 4 gallons of spray mixture in 1951, but not in 1952. That it did occur the first year suggested that confirmatory tests be made the next year, and the fact that similar results were not obtained requires further work to account for the discrepancy.

The work done on this species by other workers, using various sprays applied from the ground as cited previously, emphasizes the importance of thoroughness of application and correct timing. It is obvious that thoroughness in the sense of being able to give individual attention to each tree is impossible in airplane work. Even with the helicopter, it is difficult, and tests made by the U. S. Department of Agriculture (McIntyre 1951),[3] using a helicopter, did not indicate any advantage, with this particular insect, over the fixed wing plane, even though the spray deposit was greater (Waters & McIntyre 1953[4]).

Timing remains as the most important probable reason for the difference in results. In 1951, the spray was applied at a time when emergence was at its height and a large number of moths were in flight. That the spray could have affected the adult moths is one theory that has been advanced although there was no direct evidence on this point and adult Lepidoptera are ordinarily not considered to be very susceptible to DDT. Another, and perhaps more tenable assumption is that in 1952, owing to a period of high temperature and low rainfall, development had been more rapid, and more of the larvae had bored into the bases of the needle-fascicles, out of reach of the spray. A study of meteorological data taken at Norwich, N. Y., which is within 25 miles of the test area, revealed that average temperatures for June and July 1952 were higher than those for the same period in 1951, and that June, 1952 was drier than June, 1951.

SUMMARY AND CONCLUSIONS.—Although favorable results were obtained against the European pine shoot moth with an airplane spray of 4 pounds of DDT in 4 gallons of emulsion per acre in 1951 there was no reduction in injury by this pest when the tests were repeated in 1952. Unknown factors involved in the timing of the sprays were probably responsible for this discrepancy.

More tests are needed; but if, as is quite possible, success can be obtained only through a fortunate combination of favorable conditions most of which are unpredictable, and none of which can be controlled, then the use of the airplane for spraying with DDT to control the European pine shoot moth, as described in this paper, appears less promising than the first experiments indicated.

[3] McIntyre, T. 1951. Helicopter spraying for control of the European pine shoot with moth on the Allegheny National Forest—1951. U.S.D.A., Bur. Ent. & Pl. Quar., Div. of Forest Investigations. Unpublished report.

[4] Waters, W. E. and T. McIntyre, 1953. Airplane spraying for white pine weevil control in New York.—1952. Analysis of DDT deposit data. U.S.D.A., Bur. Ent. & Pl. Quar., Div. of Forest Insect Investigations. Special report. Unpublished.

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Effect of Field Treatments of Insecticides on Numbers of Bacteria, *Streptomyces*, and Molds in the Soil[1]

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The increasing use of DDT and other soil insecticides is not without danger of reducing soil fertility (Foster 1951). Attention has therefore been directed to possible effects of these materials on soil microörganisms and their functions. These functions include (1) decomposition of organic matter and the concomitant formation of humus, (2) ammonification or the liberation of ammonia from proteins, and (3) nitrification or the oxidation of ammonia to nitrate. Ammonification and nitrification transform the nitrogen of organic residues to soluble compounds assimilable by green plants, and are especially important because available nitrogen is so frequently a limiting factor in crop production. Other prominent activities of soil microörganisms result in the fixation of gaseous nitrogen from the atmosphere, the oxidation of sulfur to sulphate, and the reduction of nitrates under certain conditions to nitrites and free nitrogen. Study of these specialized activities requires appropriate and often complex procedures involving chemical as well as microbial analyses. However, the numbers of bacteria and molds as determined by plate counts indicate within broad limits the soil's crop producing potentialities, and since plating is relatively simple it is well suited for preliminary investigations. In general, the more organic matter present in the soil, and the better the physical and chemical condition, the greater the numbers of microörganisms.

Wilson & Choudri (1946, 1948), in laboratory studies, showed DDT and BHC in amounts considerably exceeding practical field applications had no significant effect on development of bacteria and molds, nor on certain of their physiological activities important in soil fertility. Smith & Wenzel (1947) found that 5 to 200 p.p.m. DDT were not definitely injurious and in some cases were stimulative to heterotrophic bacteria, physiological types involved largely in organic decomposition. Nitrifying bacteria were inhibited by DDT. BHC proved definitely fungicidal and also toxic to nitrifiers; chlordane was found less toxic than BHC; toxaphene was stimulating to bacteria and molds as shown by plate counts and apparently was utilized as a carbon source.

At the Oregon Station preliminary unreplicated plots laid out in 1947 to study the effects of heavy soil applications of insecticides on plant growth showed that some materials were quite toxic to many vegetables (Morrison *et al*, 1948). Observations made in these same plots during 1948 showed that adverse effects of the insecticides continued throughout the season. This led to the desire for information on effects of the insecticides on soil microörganisms in the field. Samples for plate counts were therefore taken from a series of experimental plots laid out on several different soil types for a study of various insecticides at different rates of application.

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Table 1.—**Effect of field applications of BHC, chlordane and DDT on microörganisms in different soils.**

Insecticide	Rate	pH	Microörganisms per Gram of Soil		
			Molds	Bacteria	
				Total	Strepto-myces
	Lbs./acre		*Thousands*	*Millions*	*Per Cent*
	Corvallis field No. 1, Amity silty clay loam				
None		6.5	30.3	19.4	69
BHC[1]	10	6.8	30.5	14.7	52
BHC	20	6.4	33.5	50.0	30
	Corvallis field No. 2, Wapato clay loam				
None		6.5	50.8	41.0	77
BHC	10	5.7	77.3	38.0	71
BHC	10	5.8	56.5	45.3	65
BHC	10	6.8	39.3	75.3	78
	Jefferson field, Newberg fine sandy loam				
None		6.8	36.5	15.4	66
BHC	0.25	6.3	16.0	10.8	69
BHC	0.5	6.2	23.5	14.7	62
BHC	1.0	6.2	13.6	10.1	66
BHC	5.0	6.3	18.5	15.5	69
BHC	9.0	6.7	48.5	12.3	59
Chlordane	5	6.4	20.8	14.9	62
Chlordane	10	6.2	7.0	11.7	55
Chlordane	20	6.2	18.8	14.4	61
	Astoria field, Melbourne clay loam				
None		5.4	207.5	14.5	70
BHC	1	5.4	145.0	15.0	82
BHC	5	5.2	197.5	13.0	75
BHC	9	5.5	91.5	16.6	84
DDT	5	5.3	205.5	11.7	65
DDT	10	5.8	192.5	15.5	78
DDT	20	5.6	185.0	14.5	72

[1] All BHC rates per acre are based ln gamma isomer content.

METHODS.—In most cases the insecticides were incorporated with the soil by rotary tillage, which has been found to give nearly uniform distribution and minimum loss by drag (Morrison & Crowell 1952). Wettable powders containing 20 to 25 per cent active compound were used in amounts necessary to give the indicated concentrations of actual insecticide in pounds per acre $6\frac{2}{3}$ inches (2,000,000 lbs.). One pound per acre is equivalent to 0.5 p.p.m. or 0.0344 pounds per cubic foot. The materials were diluted with sand and applied with a small fertilizer applicator before rotary tilling. On the Labish peat, water suspensions were applied with a trombone sprayer for comparison with the wettable powder-sand mixture. A power soil injector was used for the D-D fumigant mixture and ammonia.

One 226-cu. in. composite sample was taken to plow depth from each plot. Plots on the Amity, Wapato and Newberg soils were sampled 1 week after treatment. All others were sampled the same day the insecticides were applied, control samples being taken before any treatments were made. Samples were placed in paper bags or friction-top tin cans and brought to the laboratory; they were opened and allowed to stand, well isolated from each other, until just sufficiently dry for screening. They were then passed through a 10-mesh sieve and stored in friction-top cans at room temperature. Moisture determinations were made by drying 100-gm. samples for 24 hours at 105° C. A soil:water ratio of 1:5 and the glass electrode were used for pH. Counts of bacteria and *Streptomyces* were made from appropriate dilutions plated out in triplicate with sodium albuminate agar (Fred & Waksman 1928); 10 days incubation at 28° C. was employed. Molds were plated out on peptone-glucose-acid agar and counted after 5 days at 28° C. All counts were calculated on the basis of water free soil.

Analyses were made 10 to 20 days after

Table 2.—**Effect of field application of different insecticides on microörganisms in Chehalis silty clay loam soil.**[1]

Insecticide[2]	pH	Molds				Bacteria	
		Total[3]	Mucors	Penicillia	Aspergilli	Total[3]	Strepto-myces
		Thousand	*Per Cent*	*Per Cent*	*Per Cent*	*Millions*	*Per Cent*
None	6.0	26.0	8	77	5	6.4	55
BHC	6.0	23.2	12	74	4	7.2	51
DDT	6.2	22.3	9	71	4	6.2	51
EPN	6.0	26.7	9	82	1	7.1	44
Aldrin	6.0	11.0	4	82	2	5.7	47
Dieldrin	6.0	42.2	3	83	1	7.3	51
Chlordane	6.1	40.2	3	85	5	8.7	44
Parathion	5.9	20.8	10	82	1	9.8	57
Toxaphene	6.3	37.0	3	82	1	8.1	45

[1] Averages of three samples from each treated plot; values for untreated are averages of 11 samples, including composites from each of three check plots and from each treated plot before treatment.
[2] Wettable powders applied in amounts to give 10 pounds of active ingredient per acre.
[3] Numbers per gram of soil, water-free basis.

Table 3.—Effect of D-D fumigant mixture on microörganisms in Willamette silty clay loam soil.

Treatment	Rate	pH	Microörganisms per gram of Soil		
				Bacteria	
			Molds	Total	Streptomyces
			Thousands	*Millions*	*Per Cent*
Santa Clara field No. 1, spring application					
Control		6.5	16.5	52.5	19
Control		6.6	15.5	62.0	17
Average		6.6	16.0	57.3	18
D-D	48 gal/A.	6.6	4.5	15.0	17
D-D	48 gal/A.	6.6	11.5	32.5	26
Average		6.6	8.0	23.8	22
D-D plus aq. ammonia	96 gal/A. 50 lbs./A.	6.5	21.0	19.0	34
D-D plus aq. ammonia	96 gal/A. 50 lbs./A.	6.7	30.0	49.0	22
Average		6.6	25.5	34.0	28
Santa Clara field No. 2, summer application					
Controls[1]					
Minimum		6.4	24.8	1.2	44
Maximum		6.7	750.0	16.1	72
Average		6.5	235.0	8.8	54
D-D[1]	33 gal/A.				
Minimum		6.4	0.0	0.4	24
Maximum		6.8	380.0	17.8	76
Average		6.6	93.0	9.4	46

[1] 5 replicate plots.

the samples had been sieved and placed in the containers. Moisture in the prepared samples varied slightly in each set; for the several soil types it ranged from approximately 0.2 to 0.3 of the saturation capacity. A moisture content near one-half saturation is considered optimum for general microbial activity. At the time of analysis, therefore, the microörganisms in the soil had been exposed to the insecticides for about 2 weeks with moisture somewhat less than optimum but still sufficient for considerable growth and activity. The results in tables 1 to 4 inclusive are interpretable on this basis. Table 5 illustrates changes in some selected samples after storage for 5 to 10 months in closed friction-top cans.

DISCUSSION.—1. *BHC on Different Soils.*—The effect of BHC on numbers of molds as shown by data in table 1 for the four different soils is neither sufficiently great nor consistent enough to be conclusive. The general trend is one of inhibition, particularly in the Newberg and Melbourne soils. Total numbers of bacteria, except for considerable increases in two samples, showed relatively small differences due to BHC treatments. At 20 pounds per acre the insecticide strongly depressed the percentage of *Streptomyces*. This group of higher bacteria is important because of their ability to attack such resistant organic matter as lignins and celluloses. Except for the decrease noted with BHC, their numbers were little altered by any of the treatments. Chlordane and DDT decreased numbers of molds but had little effect on bacteria.

2. *Different Insecticides on One Soil.*—Comparative effects of eight different insecticides on one soil are shown in table 2. Again, BHC and DDT depressed the mold counts, though slightly. Aldrin appears definitely depressive, while dieldrin, chlordane and toxaphene produced marked increases. The differential mold counts show no significant differences: *Penicillia*, as usual for most soils, show a predominating percentage, while the mucors and *Aspergilli* occur in typically limited ranges. Differences in the bacterial counts and *Streptomyces* percentages are too small to be significant.

3. *D-D Fumigant.*—Table 3 shows that D-D fumigant applied in the spring definitely decreased the numbers of molds and bacteria. Addition of ammonia with the D-D mixture lessened the depressive effect on bacteria and stimulated the molds. The *Streptomyces* exhibited some irregular increases. Differential mold counts showed that D-D alone lowered the percentage of *Penicillium* to about one-half of their usual predominance in soils; they remained low with the addition

Table 4.—Effects of chlordane and toxaphene on microbial numbers in Lake Labish peat soil as shown by plate counts and statistical analysis.[1]

Treatment	Molds				Bacteria	
	Total	Mucors	Penicillia	Aspergilli	Total	Streptomyces
	Thousands	*Per Cent*	*Per Cent*	*Per Cent*	*Millions*	*Per Cent*
Chlordane, 4 lbs./A.	72.2	3.7	87.8	2.3	63.3	19.0
Chlordane, 6 lbs./A.	73.5	3.5	78.5	2.6	99.1	38.7
Toxaphene, 10 lbs./A.	121.3	2.4	81.9	2.0	66.8	20.7
Toxaphene, 20 lbs./A.	68.7	4.1	76.7	4.4	41.8	24.1
Controls	74.8	7.9	68.0	3.3	83.5	23.8
LSD 19–1	37.4	5.1	9.3	3.99	72.7	9.2
99–1	50.5	6.6	12.0	—	—	11.8

[1] Counts shown are averages from 3 means, each for 5 samples from each of 3 replicate plots.

Table 5.—Changes in microbial analysis of D-D treated Willamette silty clay loam soil samples[1] after storage.

Treatment	Change in Mold Count	Change in Bacterial Count	
		Total	Streptomyces
	Thousands	*Millions*	*Per Cent*
Santa Clara field No. 1, samples in storage 8 months			
Control	+39.5	−29.5	+42
D-D[2]	+21.0	+19.7	+36
D-D[2] plus aq. ammonia[3]	+3.5	+8.0	+32
Santa Clara field No. 2, samples in storage 5 months			
Control	−331.0	+57.4	+6
D-D[4]	−117.0	+46.5	+10

[1] Averages of replicates.
[2] 48 gallons per acre.
[3] 50 pounds per acre.
[4] 33 gallons per acre.

of ammonia, while *Aspergillus*, ordinarily occurring in minor proportion, was greatly increased. Significance of these alterations is not clear, but the nitrogen fertilizing value of ammonia could be in part responsible for the increase in molds. Differences between the spring and summer counts reflect seasonal variations in the soil environment. However, application of D-D in summer also produced a considerable decrease in molds, even though the numbers were much higher than for the spring counts. Differential counts were not possible on the later mold plates because mucors and other spreaders rapidly overgrew all the more usual kinds.

4. *Chlordane and Toxaphene on Peat Soil.*—The number of samples examined in the foregoing studies were necessarily limited and the data could not be statistically analyzed. While the results suggested that the several insecticides studied can have stimulating as well as depressing influences on numbers of microorganisms in the soil, no overwhelming increases or approaches to sterility were observed. The findings are therefore inconclusive. To obtain more definite information the next field trial, conducted on Lake Labish peat soil, was elaborated and more extensively sampled. Treatments and controls were replicated three times and microbial counts were made on five samples from each plot. This gave sufficient data for statistical analysis. The results are condensed in table 4.

Whether the insecticide was applied as a spray or as the wettable powder-sand mixture made no significant difference. Results for the two methods are therefore combined in the summary. The pH values which ranged from 5.6 to 6.1, averaging 5.8, have been omitted. Numbers of molds, and percentage of *Penicillia* were significantly increased by toxaphene at 10 pounds per acre. Chlordane increased the *Penicillia* without significantly altering the total mold counts. No significant changes in numbers of bacteria resulted from any treatment, but chlordane at 6 pounds per acre increased the percentage of *Streptomyces*. The anomaly of toxaphene at 20 pounds per acre having no effect, while at 10 pounds per acre it significantly increased molds and *Penicillia*, could possibly be attributed to the Arndt-Schulz phenomenon and Hueppe principle, which recognize as a general biological effect of poisons that below a minimum harmful concentration they become indifferent or stimulating. The limited water-solubility of the compound could prevent applications of 20 pounds or more per acre from becoming toxic.

5. *Prolonged Contact.*—To determine the effect of prolonged contact with the insecticide, selectee samples from the Santa Clara and Lake Labish plots were analyzed again after they had remained in

Table 6.—Changes in microbial analysis of Lake Labish plot samples[1] after 10 months storage.

Treatment	Changes in Mold Count				Change in Bacterial Count	
	Total	Mucors	Penicillia	Aspergilli	Total	Streptomyces
	Thousands	*Per Cent*	*Per Cent*	*Per Cent*	*Millions*	*Per Cent*
Control	+216	−3	+27	+1	+10	+37
Chordane, 4 lbs./A	+172	−4	−7	−3	−31	+38
Chordane, 6 lbs./A	+197	0	+4	+1	−42	+33
Toxaphene, 10 lbs./A.	+93	−1	+3	−1	−26	+45
Toxaphene, 20 lbs./A.	+164	−3	+5	−4	+24	+30

[1] Averages of randomly selected replicates.

air-tight storage at room temperature for 5 to 10 months. Changes from the original counts made shortly after samples were collected in the field are shown in tables 5 and 6. In Santa Clara samples it is apparent that molds and bacteria could multiply in the D-D treated soil, except that in the summer treated soil the molds decreased, but less so than in the controls. Molds increased in the peat soil samples, but less extensively in the presence of the insecticides. The bacteria decreased markedly with chlordane; toxaphene gave results not necessarily inconsistent with the original counts in table 4, considering the food supply and other environmental factors to be uniform in all samples. Changes in *Streptomyces* were little influenced by the fumigant or insecticides. It would seem that under field conditions, where deterioration or loss of the various compounds could well be more rapid than in stored samples, that the effects of prolonged contact would be minimized. While chlordane appeared to inhibit bacteria in the soil on storage, effects of the other toxicants were not distinctly altered with time.

Conclusions.—No immediate harmful effects on soil microörganisms were caused by field applications of any of the insecticides studied. Otherwise the results are indicative only. Strong and readily observable effects were definitely not produced. None of the treatments resulted in either an approach to sterility or a manyfold increase in molds, bacteria or *Streptomyces;* nor were marked changes in proportions of these microbes produced. In some cases increases exceeding 100 per cent and decreases as much as 80 per cent were observed, but such variations were found with samples from replicate plots as well as with samples from differently treated plots. Adequate microbial analysis of field plots requires many samples, and is laborious and time-consuming. Routine examinations of spot samples are likely to reveal little else than overwhelming effects. In but one of the field trials was it practicable to obtain a number of samples adequate for statistical analysis of the data. Laboratory experiments under controlled conditions, using composite bulk samples from the field, can offer more extensive and reliable information from the study of such essential microbial activities as nitrification, sulfur oxidation and organic matter decomposition. Such studies on a variety of soil types are now in progress.

SUMMARY.—Field applications of BHC and DDT depressed mold counts in several types of soil, including a sandy loam, silty clay loams, and clay loams. Toxaphene significantly increased molds and the percentage of *Penicillia* in a peat soil. BHC in some instances increased numbers of bacteria, but the counts for this group of organisms were on the whole not significantly altered by any of the toxicants. Chlordane showed no definite toxic effects. The results are in general agreement with reports by previous investigators.

In one field trial aldrin inhibited molds while dieldrin increased their numbers; parathion and EPN had little effect. Numbers of bacteria were not significantly changed by these chemicals.

D-D fumigant definitely decreased numbers of molds and bacteria, but when ammonia was added with the D-D molds were increased and bacteria were less depressed.

Counts repeated on stored samples showed that effects of D-D, chlordane and toxaphene were not distinctly altered in 5 to 10 months.

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Effect of Field and Laboratory Treatments with BHC and DDT on Nitrogen Transformations and Soil Respiration[1]

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Preliminary plate count studies on soils treated with insecticides in the field at various rates showed that toxaphene at 10 pounds per acre significantly increased numbers of molds and percentage of *Penicillia*. It was found also that D-D fumigant at 48 and 96 gallons per acre was definitely depressive to molds and bacteria, but that this depression was considerably lessened by applying aqua ammonia at 50 pounds per acre with the fumigant. Aside from these findings, the extensive data indicated only that no outstanding inhibitive or depressive effects were produced by the toxicants studied (Bollen *et al.* 1954). Plate counts are laborious, especially when applied to the number of samples required for statistical analysis, and the results bear only a general relationship to soil fertility. For further work it appeared more feasible to make laboratory studies on the influence of insecticides on some important soil microbial functions.

Results of such studies made on bulk soil samples from BHC and DDT treated plots are presented here. The plots were laid out in the spring on Cove clay adobe soil as described by Morrison *et al.* (1948). The BHC plot received 275 pounds of BHC per acre, applied as a technical product containing 10 per cent of the gamma isomer. DDT was applied as a commercial wettable powder at a rate equivalent to 137.5 pounds actual DDT per acre. Composite soil samples weighing approximately 100 pounds each were taken from the control and treated plots after fall plowing 7 months later. These were sieved through a $\frac{1}{4}$-inch mesh screen when collected; later they were reduced to 10-mesh per inch, thoroughly mixed, and stored in covered 50-gallon cans for use as required. Analytical data are given in table 1.

Table 1.—Analysis of cove clay adobe soil (data on water-free basis).

	From Entomology Field Plots		
	Control	DDT[1]	BHC[2]
Moisture—%	23.9	25.3	20.6
Saturation capacity—%	60.0	63.1	63.1
pH	6.6	6.6	6.7
Nitrogen			
Ammonia, p.p.m.	16	28	33
Nitrite, p.p.m.	1	1	1
Nitrate, p.p.m.	25	18	8
Kjeldahl, %	0.199	0.234	0.222
Total carbon, %	2.291	3.187	2.989
C/N ratio	11.5	13.6	13.5
Microörganisms			
Molds—thousands	13.5	26.0	19.5
Mucoraceae, %	35	26	28
Penicillia, %	55	[3]	[3]
Aspergilli, %	10	[3]	[3]
Bacteria, millions	58.0	18.0	23.5
Streptomyces, %	20	20	21

[1] Received DDT at 137.5 lbs./A, actual.
[2] Received BHC at 275 lbs/A.
[3] Overgrown by *Mucoraceae*.

The greater amounts of Kjeldahl nitrogen and total carbon in the treated plot samples is not attributable to the insecticides, nor to any known previous cultural history before treatment. Aside from natural or introduced factors of unknown origin, it is possible that irregularities in distribution and incorporation of crop residues caused some of the variation found. Differences shown in total molds correspond approximately to the differences in organic matter and C/N ratio. Therefore, the greater numbers found in the treated plots cannot be attributed directly to the insecticides. The decreases in bacterial numbers, however, definitely appear to result from the BHC and DDT treatments.

Soil from the check plot was treated in the laboratory with alpha-, beta-, delta-, and gamma-BHC, each at 1000 p.p.m., to investigate the effect of each isomer on development of bacteria and molds, on ammonification and nitrification of peptone, and on nitrification of ammonium sulfate. The effect of field treatment with DDT and BHC on these microbial functions and on soil respiration in plot sam-

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[2] Bacteriologist and Associate Entomologists, respectively.

Table 2.—Effect of BHC isomers on development of molds and bacteria in cove clay adobe soil.[1]

Treatment[2]	Molds				Bacteria	
	Total per Gram of Soil[3]	Mucors	Penicillia	Aspergilli	Number per Gram of Soil[3]	Streptomyces
	Thousands	*Per Cent*	*Per Cent*	*Per Cent*	*Millions*	*Per Cent*
Soil only	28	3	91	0	1.7	26
BHC-alpha	36	17	72	0	5.4	36
BHC-beta	15	12	83	0	30.0	31
BHC-delta	19	5	79	0	2.0	35
BHC-gamma	4	30	63	0	10.5	25
Dextrose	70	3	78	0	70.0	26
Dextrose+BHC-alpha	35	4	86	0	107.0	27
Dextrose+BHC-beta	49	10	79	0	157.5	22
Dextrose+BHC-delta	105	1	98	0	127.5	34
Dextrose+BHC-gamma	78	4	86	0	178.5	19
Dextrose+NH_4NO_3	68	2	95	0	68.0	33
Dextrose+NH_4NO_3+BHC-alpha	35	6	90	0	100.0	40
Dextrose+NH_4NO_3+BHC-beta	32	3	85	0	116.5	43
Dextrose+NH_4NO_3+BHC-delta	83	4	94	0	143.5	38
Dextrose+NH_4NO_3+BHC-gamma	80	3	85	0	148.5	27

[1] Incubated 21 days at 28° C.
[2] BHC isomers added at 1000 p.p.m.; dextrose at 5000 p.p.m.; NH_4NO_3 at 125 p.p.m. N to give C/N = 16.
[3] Water-free basis.

ples was similarly studied, but without laboratory additions of any insecticides.

In all cases, the laboratory treatments were made in duplicate, using samples of soil equivalent to 100 grams on the water-free basis. The BHC isomers employed were supplied by the California Spray-Chemical Corporation; before use the crystals were ground in an agate mortar and passed through a 100-mesh screen. Bacto peptone was used for the ammonification studies. These materials were added in the dry state and mixed with the soil. After transferring to ½-pint milk bottles, sufficient distilled water was added to bring the moisture to the optimum of 60 per cent saturation. Other chemicals, all of reagent grade, were added in solution when required, the volume being subtracted from the water subsequently added. The bottles of prepared soil were covered with caps perforated for aeration and incubated at 28° C. for the time indicated in the tables. Moisture loss was restored by weight every 4 or 5 days.

Numbers of bacteria and molds were determined by plate counts as described in the previous paper (Bollen *et al.* 1954). Ammonia was determined by distillation from phosphate buffer solution at pH 7.4,

Table 3.—Ammonification and nitrification of peptone in the presence of BHC isomers in cove clay adobe soil.[1]

Treatment[2]	Nitrogen (p.p.m.)						Added Peptone	
	Found After Incubation			Increase Due to Treatment			Nitrogen Ammonified Per Cent	Nitrogen Nitrified[3] Per Cent
	NH_4^+	NO_2^-	NO_3^-	NH_4^+	NO_2^-	NO_3^-		
Soil only	1	0.5	63					
BHC-alpha	4	2.3	49	3	1.8	−14		
BHC-beta	3	2.0	58	2	1.5	−5		
BHC-delta	2	2.1	88	1	1.6	25		
BHC-gamma	2	0.5	35	1	0.0	−28		
Peptone	370	0.5	37	369	0.0	−26	37	0
Peptone+BHC-a	360	7.5	82	359	7.0	19	36	3
Peptone+BHC-b	350	4.5	105	349	4.0	42	35	5
Peptone+BHC-d	460	5.0	88	459	4.5	25	46	3
Peptone+BHC-g	430	6.9	70	429	5.5	7	43	1

[1] Incubated 16 days at 28° C.
[2] BHC isomers added at 1000 p.p.m.; peptone added at 1000 p.p.m. N.
[3] As nitrite and nitrate.

Table 4.—Nitrification of ammonium sulfate in the presence of BHC isomers in cove clay adobe soil.[1]

TREATMENT[2]	NITRATE NITROGEN FOUND AFTER INCUBATION (p.p.m.)		ADDED NH_4^+ NITRIFIED
	NO_3^-	Increase	
			Per cent
Control	95		
BHC-alpha	103	8	
BHC-beta	103	8	
BHC-delta	123	28	
BHC-gamma	113	18	
$(NH_4)_2SO_4$	120	25	8
$(NH_4)_2SO_4$+BHC-alpha	133	38	13
$(NH_4)_2SO_4$+BHC-beta	250	155	52
$(NH_4)_2SO_4$+BHC-delta	106	11	4
$(NH_4)_2SO_4$+BHC-gamma	175	80	27

[1] Incubated 20 days at 28° C.
[2] BHC isomers added at 1000 p.p.m.; $(NH_4)_2SO_4$ at 300 p.m.N.

using 10-gram samples of soil, water-free basis (Shrikhande 1941).

One to five soil-water extracts were analyzed by the sulfanilic acid-alpha napthylamine (A.O.A.C. 1945) and phenoldisulfonic acid (Harper 1924) methods for nitrites and nitrates. Respiration and dextrose decomposition were studied by periodic determination of CO_2 evolved at 28° C., using the apparatus and general procedure described by Bollen (1941). The CO_2 absorbed in N/1 NaOH was determined by double titration with a Beckman automatic titrator.

RESULTS.—Plate counts made on laboratory treated soils after 3 weeks incubation show (Table 2) that all the isomers of BHC at 1000 p.p.m. definitely increased the numbers of bacteria, the gamma form having the greatest and most consistent influence. Dextrose, with and without ammonium nitrate, considerably increased microbial development, and with this stimulus the molds showed consistent response to the BHC additions. The alpha and beta forms were depressive, while the delta and gamma isomers gave increased numbers. No definite effects on the percentage of mucors or *Penicillia* are apparent. *Streptomyces* were reduced by gamma-BHC, although this compound gave outstanding increases in the total number of bacteria.

The effect of BHC isomers on ammonification of peptone is shown in table 3. Alpha- and beta-BHC had no influence, but with the delta and gamma forms ammonia production considerably increased. Nitrate formation from peptone, probably limited by the abundance of soluble organic substance added, was so small in all cases that the differences are not of significance. It may be noted, however, that more nitrate was found with the beta isomer, which is true also for nitrification of ammonium sulfate (table 4). Nitrification of this compound was increased extensively in the presence of the gamma isomer also. In no case did BHC in any form inhibit nitrification. Nitrification of the soils own nitrogen, in the absence of added peptone or ammonium sulfate, was greatest in the presence of delta-BHC. The nitrification was not extensive, however, and the apparent differences with other isomers involving relatively small con-

Table 5.—Ammonification of peptone in cove clay adobe soil field-treated with DDT and BHC.[1,2]

PLOT TREATMENT[3]	NITROGEN FOUND (p.p.m.)						AMMONIFICATION, 7 DAYS	NITRIFICATION, 14 DAYS
	7 Days			14 Days				
	NH_4^+	NO_2^-	NO_3^-	NH_4^+	NO_2^-	NO_3^-	Per Cent	Per Cent
Check								
Control	9	0.1	20	9	0.1	19		
Peptone	479	0.5	5	323	0.1	37	47	2
DDT								
Control	10	1.0	10	9	0.1	9		
Peptone	410	4.3	1	311	0.1	30	40	2
BHC								
Control	13	1.0	5	7	0.1	12		
Peptone	424	3.0	0	326	0.1	31	41	2

[1] BHC at 275 lbs./A; DDT at 137.5 lbs./A, actual.
[2] Incubated at 28° C.
[3] Peptone added at 1000 p.p.m. N.

Table 6.—Nitrification of ammonium sulfate in cove clay adobe soil field-treated with DDT and BHC.[1]

Plot Treatment	Nitrogen Found (p.p.m.)				Nitrification	
	10 Days		20 Days		10 Days	20 Days
	NO_2^-	NO_3^-	NO_2^-	NO_3^-	Per Cent	Per Cent
Check						
Control	2	21	0.1	33		
$NN_4/_2SO_4$[2]	8	29	0.1	80	5	16
DDT						
Control	12	11	0.1	55		
$NH_4/_2SO_4$	15	21	0.1	90	4	12
BHC						
Control	8	5	0.1	44		
$NH_4/_2SO_4$	16	13	0.1	54	5	3

[1] BHC at 275 lbs./A; DDT at 137.5 lbs./A, actual.
[2] Ammonium sulfate at 300 p.p.m. N.

centrations of nitrate have little indicative value.

In samples from field plots treated with BHC at 275 pounds per acre and DDT at 137.5 pounds actual per acre, ammonification of peptone (table 5) was slightly retarded; there was little transformation to nitrate and essentially no differences in comparison with the check plot soil. Nitrification of ammonium sulfate (table 6) was appreciable in the check plot sample; little less nitrate was formed in the DDT treated soil, but nitrification was strongly inhibited in soil from the BHC plot. These results for BHC are at variance with the effects immediately following treatment in the laboratory with a much higher concentration of the gamma isomer, which gave increased ammonification and nitrification.

The respiration experiment (tables 7 and 8) shows that the microbial capacity to decompose organic matter was not appreciably influenced by field treatment of the soil with BHC or DDT. Decomposition of the native organic matter was slow in each case, although it would seem that more CO_2 would have been produced from the treated plot samples since these contained more organic matter and showed a wider C/N ratio. The rate and extent of decomposition of added dextrose was essentially the same for the treated and check plots.

Results of plate counts made on these soils at the close of respiration are in fair agreement with corresponding data for the original samples (table 1). Total numbers of molds, particularly with added dextrose, were higher in presence of the insecticides while the reverse is true for numbers of bacteria. The percentage of

Table 7.—Respiration and decomposition of dextrose in cove clay adobe soil field-treated with DDT and BHC.[1]

Plot Treatment[2]	CO_2 Evolution								Apparent Decomposition of Dextrose
	Mg. C per 100 Gm. Soil, Cumulative on Days Indicated							Less Control	
	2	4	7	14	24	36	46		Per Cent
Check									
Control	1	3	6	10	19	28	35		
Dextrose	89	106	127	149	167	185	200	165	83
DDT									
Control	2	2	6	9	13	21	28		
Dextrose	84	104	117	136	156	177	198	170	85
BHC									
Control	4	8	10	15	20	27	34		
Dextrose	79	94	111	133	156	177	191	157	79

[1] BHC at 275 lbs. per A; DDT at 137.5 lbs. per A, actual.
[2] Dextrose at 2000 p.p.m. carbon.

Table 8.—**Microörganisms found at close of 46-day respiration experiment on cove clay adobe soil field-treated with DDT and BHC.**

Plot Treatment[1]	pH	Molds					Bacteria	
		Total[2]	Mucors	Penicillia	Aspergilli	Trichoderma	Total[2]	Streptomyces
		Thousands	Per Cent	Per Cent	Per Cent	Per Cent	Millions	Per Cent
Check								
Control	6.6	59	8	85	2	2	50	4
Dextrose	6.8	77	4	78	0	1	70	6
DDT								
Control	6.6	62	3	88	2	0	39	4
Dextrose	6.5	83	6	90	2	0	44	6
BHC								
Control	6.7	47	6	85	0	2	26	6
Dextrose	6.8	122	8	83	4	1	50	6

[1] As indicated in table 7.
[2] Numbers per gram of soil, water-free basis.

Streptomyces, although considerably lower than in the field samples, again was practically unaltered by the insecticides. Similarly the differential mold counts were relatively uniform. The small changes noted in pH values are not significant.

DISCUSSION.—The observed increases in bacterial numbers following addition of BHC isomers to soil in the laboratory are in contrast with the decrease observed in the field-treated soil. In the previous paper results showing increases as well as decreases were obtained with several soil types following field application of BHC at rates of 0.25 to 20 pounds gamma isomer per acre. The effect observed in any case is likely to depend upon: (1) the time elapsed between application and testing, since growth and multiplication exhibit sequential phases of increase and decline; (2) the soil type, determined largely by physical and chemical characteristics, including organic matter and pH; and (3) variations in environmental factors, especially moisture, temperature and aeration. Results of laboratory experiments under controlled conditions would seem to be reliably indicative.

Increases or decreases in microbial numbers in the presence of BHC and other chlorinated hydrocarbon insecticides are difficult to explain in view of the extremely low water-solubility of such compounds. This solubility is of the order of a few tenths part per million, and while it may be sufficient for certain inhibitive or toxic effects it appears totally inadequate to account for increases by serving as a food supply. Stimulative effects, not only upon growth, but also upon physiological activity such as ammonification and nitrification, are probably due to intervention of traces of the insecticide in certain enzyme or other catalytic systems involved in nutrition of the cell. Some support for this is to be found in the apparent specificity of the different isomers of BHC in their effect or lack of effect on ammonia and nitrate production.

While lack of response to BHC and similar compounds could be ascribed to their limited solubility such general functions as soil respiration involve so great a variety of microörgansims that inhibition or stimulation of a number of species could occur without affecting the overall activity of the microbial population as a whole. This applies similarly to plate counts, where numbers rather than specific organisms are determined. Pure culture studies could reveal inhibitions or stimulations of certain species, although such effects might not be evident when studying activities of mixed cultures as they occur in the soil.

The importance of soil type should be emphasized because quantitative and qualitative differences in soil organic matter and colloids influence absorption and exchange phenomena which may cause inactivation or chemical transformation of insecticidal compounds. Since the results reported in this paper were obtained with a single soil type, they are not necessarily indicative of the effects of the insecticides on soils in general.

The significance in soil fertility of the observed inhibiting and stimulating effects

of the insecticides is probably not great. More extensive alterations in the microbial population and their activities occur with variations in environmental conditions resulting from cultural practices and seasonal changes. Since extreme effects were not shown even by massive doses of the insecticide, it may be concluded that BHC at rates in practice for insect control will not sufficiently influence the soil microflora to cause appreciable changes in soil fertility.

SUMMARY.—Different isomers of BHC added to a clay adobe soil at 1000 p.p.m. in the laboratory produced different effects on numbers of bacteria and molds developed on incubation; the isomers also had different influence on ammonification and on nitrification.

The gamma isomer of BHC considerably increased the bacterial population, although *Streptomyces* were decreased. The other isomers gave smaller increases.

When mold development was favored by adding dextrose to the soil, delta and gamma isomers of BHC increased the numbers, while the alpha and beta forms caused a depression. In the absence of dextrose, where the molds were lesser in numbers, all isomers except the alpha were inhibiting.

Delta and gamma isomers of BHC increased ammonification of peptone; the other isomers had no effect.

Nitrification of ammonium sulfate was increased with the beta and gamma isomers of BHC. In field treated soil, however, subsequent formation of nitrates in the laboratory was decreased where BHC had been added at the rate of 275 pounds per acre.

CO_2 evolution and dextrose decomposition in the soil that had been field-treated with BHC and DDT was the same as for the untreated soil.

The gamma isomer of BHC appeared quantitatively and qualitatively more effective than the other isomers in producing response by soil microörganisms.

The stimulations and inhibitions observed are considered to be insufficiently intensive to materially influence fertility of the soil.

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Insecticide Tests to Control the Alfalfa Weevil and the Meadow Spittlebug in Maryland[1]

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The alfalfa weevil, *Hypera postica* (Gyll.), an important pest of alfalfa in the west for many years, was first found in the East in 1951. Poos and Bissell (1953) reported extensive damage in several areas in Maryland during 1952. In 1953 the larvae caused severe injury in Maryland on the Eastern Shore and in the area north of Baltimore. In many fields the first crop of alfalfa was a complete loss.

The damage by this insect combined with that caused by nymphs of the meadow spittlebug, *Philaenus leucophthalmus* (L.), is now a serious problem for the eastern alfalfa growers. Experiments were conducted during 1953 to determine whether a single application of an insecticide would be effective against both insects. In the course of this work certain information on the seasonal history of the alfalfa weevil was recorded.

Seasonal History of the Alfalfa Weevil.—In 1953 the first adult was collected on March 24 by T. L. Bissell of the Department of Entomology, University of Maryland. Sweeps taken periodically throughout the season showed that adults were most numerous late in April, when they averaged 16 per 100 sweeps of a 15-inch net. Adults continued to be abundant until early July. The numbers collected from mid-July to early October fluctuated from 0.3 to 1.4 per 100 sweeps. In late October and early November the population increased, averaging 7.6 adults per 100 sweeps. Adults have continued to be active on mild days and were swept from one field on December 8.

Eggs were first observed in the field on April 8 and could be found rather easily as late as June 3. No eggs were found during the summer months. However, adults collected in the field on August 7 deposited eggs in the outdoor insectary on August 14. These eggs hatched on August 19. Eggs were collected in the field on November 2 following the increase in the adult population during late October. A few masses collected on this date and kept in the insectary hatched on November 18–19. Additional masses were collected as late as December 8.

Larvae were first found on April 14. They were most abundant during the first half of May, when collections from several fields averaged more than 2400 per 100 sweeps. Populations were light throughout the remainder of the season, although there were minor fluctuations. Larvae of all sizes were collected as late as December 8, indicating that at least a part of the population has more than one generation per year. Cocoons were found on May 4 and the first pupa on May 6. On May 22 two men picked about 1700 cocoons from alfalfa plants in a heavily infested field in 40 minutes. The finding of empty cocoons on May 12 indicated that emergence had begun.

Control Experiments.—Five experiments with insecticides for control of the alfalfa weevil and the meadow spittlebug were conducted during 1953. All the insecticides were applied as emulsion sprays, with power equipment calibrated to apply approximately 10 gallons per acre. The effect of the treatments was determined by collecting samples with a 15-inch net. None of the treatments significantly affected the number of adult weevils taken in the samples; so only the data on alfalfa weevil larvae and meadow spittlebug nymphs will be presented.

Experiment 1.—At Gambrills, plots 44 by 200 feet, arranged in a randomized block, replicated 4 times, were sprayed on March 31 when the plants averaged 6 inches tall. Samples of 20 sweeps per plot were taken on April 20 and 40 sweeps per plot on May 11. In the samples taken on April 20 the weevil populations were so light that no conclusions could be drawn, although no larvae were found in the plots treated with heptachlor, dieldrin, or methoxychlor. The data for the samples taken on May 11 are given in table 1.

[1] Presented before the meeting of the Eastern Branch of the Entomological Society of America, Philadelphia, Pa., November 16–17, 1953.

[2] In cooperation with the Department of Entomology of the University of Maryland.

Table 1.—Effect of different insecticides on populations of alfalfa weevil larvae and spittlebug nymphs. Experiment 1, Gambrills, Maryland.

Material	Rate per Acre	Population per 160 Sweeps May 11		Reduction Below Untreated Check	
		Weevil Larvae	Spittlebug Nymphs	Weevil Larvae	Spittlebug Nymphs
	Pounds	*Number*	*Number*	*Per Cent*	*Per Cent*
Untreated	—	847	509	—	—
Dieldrin	0.25	311	1	63.3	99.8
Heptachlor	0.23	436	6	48.5	98.8
Methoxychlor	1.56	448	0	47.1	100.0
Endrin	0.24	527	2	37.8	99.6
Toxaphene	1.64	602	0	28.9	100.0

Dieldrin was the most effective material against weevil larvae, followed in order by heptachlor, methoxychlor, endrin, and toxaphene. All the treatments were very effective against the meadow spittlebug, reducing the population more than 98 per cent.

Experiment 2.—In Harford County, plots of alfalfa 43 by 100 feet in a randomized block, replicated 4 times, were sprayed on April 2. On this date the plants ranged from 4–8 inches in height. The population was sampled on April 29 by taking 40 sweeps per plot and on May 15, by taking 10 sweeps per plot. The data for this experiment are recorded in table 2.

When sampled on April 29 heptachlor was the most effective material for control of alfalfa weevil larvae. Endrin and dieldrin also reduced the population more than 90 per cent. Methoxychlor and toxaphene were less effective. There was a very heavy increase in both treated and untreated plots between April 29 and May 15. On the latter date the plots treated with heptachlor had less than half as many larvae as the untreated plots. The plots treated with dieldrin and endrin showed smaller reductions. Those treated with methoxychlor or toxaphene contained a heavier population than the untreated plots.

The data on spittlebug control obtained on May 15 showed more than 96 per cent reduction with all the insecticides except toxaphene, and that insecticide caused a reduction of 86 per cent.

Experiment 3.—Similar results were obtained from another series of plots in Harford County treated on April 15. The treatments were applied to plots 43 by 200 feet, arranged in a randomized block and replicated 4 times. The plants ranged from 6–13 inches tall and averaged approximately 8 inches. On April 27 and May 13 the population was sampled by taking 40 sweeps per plot. The data obtained are given in table 3.

On April 27 the plots treated with heptachlor again showed almost complete reduction of weevil larvae. The dieldrin treatment was next in effectiveness, fol-

Table 2.—Effect of different insecticides on the population of alfalfa weevil larvae and spittlebug nymphs. Experiment 2, Harford County, Maryland.

Material	Rate per Acre	Population per			Decrease or Increase Over Untreated Check		
		160 Sweeps April 29	40 Sweeps May 15		April 29	May 15	
		Weevil Larvae	Weevil Larvae	Spittlebug Nymphs	Weevil Larvae	Weevil Larvae	Spittlebug Nymphs
	Pounds	*Number*	*Number*	*Number*	*Per Cent*	*Per Cent*	*Per Cent*
Untreated	—	172	2879	129	—	—	—
Heptachlor	0.28	2	1367	5	98.8	52.5	96.1
Endrin	0.29	8	2127	3	95.3	26.1	97.7
Dieldrin	0.34	12	1732	2	93.0	39.8	98.4
Methoxychlor	1.87	27	3048	2	84.3	+5.9	98.4
Toxaphene	1.92	89	2987	18	48.2	+3.8	86.0

Table 3.—Effect of different insecticides on the population of alfalfa weevil larvae and spittlebug nymphs. Experiment 3, Harford County, Maryland.

Material	Rate per Acre	Population per 160 Sweeps			Decrease or Increase Over Untreated Check		
		April 27	May 13		April 27	May 13	
		Weevil Larvae	Weevil Larvae	Spittlebug Nymphs	Weevil Larvae	Weevil Larvae	Spittlebug Nymphs
	Pounds	*Number*	*Number*	*Number*	*Per Cent*	*Per Cent*	*Per Cent*
Untreated	—	1009	5680[1]	820	—	—	—
Heptachlor	0.22	2	3095	1	98.8	45.5	99.0
Dieldrin	0.11	131	7115	20	87.0	+25.3	97.6
Endrin	0.27	173	7290	0	82.8	+28.3	100.0
Methoxychlor	0.99	177	7432	21	82.4	+30.8	97.4
Toxaphene	1.41	298	6728	0	70.5	+18.4	100.0

[1] The untreated plots were nearly 100 per cent defoliated on this date.

lowed in order by endrin, methoxychlor, and toxaphene. By May 13 the larval population had increased many fold; the untreated plots were entirely defoliated but had fewer larvae than most of the treated plots. Heptachlor was the only treatment still showing any reduction.

Against the spittlebug population all the materials were very effective and the population was reduced more than 97 per cent.

Experiment 4.—At Gambrills acre-dosages of methoxychlor at 0.95 pound, toxaphene at 1.33 pounds, heptachlor at 0.26 pound, and endrin at 0.20 pound were applied on April 17 to unreplicated plots each 0.75 acre in size. The treatments were evaluated on April 20 by taking 20 sweeps and on May 14 by taking 40 sweeps per plot. No effects of the treatments were observed on April 20, as only 2 adult weevils were taken. On May 14 heptachlor, methoxychlor, toxaphene, and endrin had reduced the population of weevil larvae 70.0, 63.4, 46.0, and 44.6 per cent, respectively. All the treatments were very effective against the meadow spittlebug, reducing the population of nymphs more than 98 per cent.

Experiment 5.—Late in May, when the first hay crop was cut from one field in Harford County, many larvae and adults of the alfalfa weevil still remained on the stubble. To determine whether the second crop would benefit by treatment of the stubble, unreplicated plots of 1 to 4 acres were sprayed on May 27 with heptachlor at 0.51 pound, endrin at 0.23 pound, dieldrin at 0.25 pound, and Q-137 (Perthane) at 1.64 pounds per acre. Counts were made on June 2 and again on June 9 of the adults and larvae in 20 samples, each 1 square foot in area, from each plot.

On June 2 numerous adults were severely damaging the new shoots in the untreated plot, but only a few larvae or adults were found in the treated plots. On June 9 only a very light population of larvae was found in the treated or untreated plots; adults were more numerous in the treated plots, possibly because the foliage was more luxuriant.

On June 9 there was practically no regrowth in the untreated plots, whereas plants in the treated plots averaged 6 to 8 inches tall. On June 17 a total of 30 plants selected at random in each plot were measured. Plants in the untreated plot averaged 7.1 inches in height as compared with 11.5, 10.9, 9.8, and 8.7 inches for plants in the plots treated with heptachlor, dieldrin, endrin, and Q-137, respectively.

Discussion.—These experiments show that the application of insecticides, especially heptachlor and dieldrin, in late March or early April gives promising control of alfalfa weevil larvae on first-crop alfalfa in Maryland. The materials were not entirely effective against larvae from eggs that hatch 2 to 3 weeks after spraying, but thereafter some of the more promising treatments still gave considerable protection. Harvesting the first crop was delayed more than 2 weeks beyond the normal time in one of the experimental fields in which some larval damage from the increased population occurred even in plots treated with hepta-

chlor or dieldrin. Therefore, for best results the hay crop should be cut promptly. The amount of insecticide residues, if any, present on the forage at harvest may indicate the need for additional data on the timing of applications in relation to the cutting of the first crop. This report is considered preliminary and any recommendations must await the results of residue determinations from the forage samples taken at cutting time.

All the insecticides applied at the dosages used in these experiments effectively controlled the meadow spittlebug, indicating that a single application may be used to control both this pest and the alfalfa weevil.

The spraying of alfalfa stubble for control of alfalfa weevil larvae and adults after removal of the first hay crop hastened the regrowth of the next crop. The benefits to be gained from stubble treatment need to be further investigated.

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Additional Studies on the Effect of Field Applications of Insecticides on Honey Bees

F. V. LIEBERMAN, G. E. BOHART, G. F. KNOWLTON, and W. P. NYE[1]

Choice of an insecticide treatment to be used on a legume seed crop in bloom should be determined by its hazard to bees as well as its economic effectiveness in controlling harmful insects. This is true not only because bees provide the cross-pollination essential to high yield of quality seed but also because most beekeepers still depend on a honey crop for their living.

In 1947 the staff of the U. S. Legume Seed Research Laboratory at Logan, Utah, initiated a study to ascertain which of the principal new organic insecticides could be applied to seed alfalfa in bloom without creating a serious threat to honey bees. This work has been continued each season with the exception of 1951. Most of the studies made prior to 1950 have been published (Todd *et al.* 1949, Knowlton *et al.* 1950). This paper is a report of 16 field tests conducted in 1950, 1952, and 1953.

Procedure.—To obtain results similar to those found in commercial practice, we have continued to conduct tests in the field rather than in laboratory or field cages. The procedures were basically the same as those previously described, but improvements made warrant a brief redescription.

Approximately 5 acres of 2-year-old alfalfa were provided each year by the Utah Agricultural Experiment Station in an area of little competing bloom that could be maintained reasonably free of extraneous honey bees and insecticide applications. About 1 week before the first test from 14 to 18 strong hives of bees were placed in a small plot adjacent to the alfalfa field. The plot was cleared of vegetation, smoothed, and marked off into an examination area within which would be found most of the adult bees dying at the hives.

Counts of bees working the field were made by recording the number instantaneously present within square-yard counting stations. These stations were marked off with a white string supported on corner lath stakes and were distributed systematically through the field, 68 being used in 1950 and 100 in the following years. Counts of dead bees in the field were made on 48 to 50 two-square-yard areas located systematically away from these stations. Since the alfalfa on these areas was sickled off to facilitate visual examination

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of the field litter and soil surface, new areas were selected each day that dead bees were counted.

Dead bees were picked up around the hives between 6 and 7 A.M. Field visitors were counted between 10 and 11 A.M. and 1:30 and 2:30 P.M. The counts of dead bees in the field were made between 7 and 11 A.M., the fresh dead bees found being those that died while visiting flowers the previous day.

All the insecticides were applied during hours when few bees were visiting the field. Morning applications were made between 6 and 7 A.M., m.s.t. Evening applications were made after 7 P.M. A duster or sprayer mounted on a small farm tractor and connected with the power take-off was used. The duster was equipped with 12 V-type nozzles 17 inches apart and connected by separate lines of flexible 2-inch tubing to a common fan chamber. The sprayer had a 30-foot boom fitted with 18 nozzles discharging a flat, fan-shaped spray. In 1953 sprays were applied at the rate of 12 gallons per acre, in previous seasons at 8 gallons per acre. Tractor speed during all applications was approximately 5 m.p.h. Pressure in the spray boom was maintained at 60 pounds per square inch.

The number of bees exposed to each treatment was estimated from counts at all stations on the day of application at the two periods of expected peak visitation. The higher of these totals multiplied by the proper factor for field size was then designated as the exposed population. The number of insecticide-killed bees dying at the hives was estimated by correcting the total number of bees picked up during the period of a test by a daily normal based on the dead bees found in the examination area for at least 2 days prior to treatment. The number of insecticide-killed bees dying in the field was estimated by multiplying the number of freshly killed poisoned bees found in all examination areas by the proper factor for field size. Bees were determined to be freshly dead and/or poisoned by noting deterioration of the digestive tract and the accumulation of fluids in the hind gut and comparing these changes with those occurring in check bees. Check bees were removed from a hive at the time of field treatment and placed in lots of five in small screen cages. One lot was killed by pinching, and several other lots were killed by placing the cages in the path of the application equipment and allowing them to be sprayed or dusted. All check bees were then placed in a representative spot in the field. One lot of sprayed bees was examined each day at the time dead bees found in the field were classified. Pinched bees were examined at this time only on the first day.

The total mortality resulting from an application is expressed as a percentage of the maximum number of bees visiting the field at any one time on the first day of exposure. This estimate is conservative in that it does not take into account bees leaving the field but not reaching the colonies or those returning to other colonies within flight range of the test field. On the other hand, the method of expressing field visitation probably exaggerates the true mortality, since it represents only the largest number on the field at one time and not the total of all bees visiting the field on the day of treatment.

RESULTS.—Briefly summarized, tests conducted in the period 1947–49 (Todd *et al.* 1949) showed that (1) mortality of honey bees caused by field applications of the principal organic insecticides was confined to the field force and in most cases was essentially complete within 48 hours; (2) toxicity of toxaphene in seven tests at dosages providing effective control of several detrimental insects was always distinctly less than 10 per cent; and (3) except for methoxychlor, the insecticides tested were sufficiently toxic (more than 10 per cent) in at least one trial that further studies were considered necessary to learn whether there was a dosage safe for bees.

The objectives of the 1950 tests were to procure additional data on the effect of DDT and chlordane and again to compare spray and dust applications. Dosages selected for testing were those best suited for use in the control of alfalfa seed insects under Utah conditions, and applications of toxaphene were included. The results of these tests are presented in table 1.

The mortalities in these tests agree with those obtained in previous years. Toxaphene as a spray or dust killed few bees, DDT spray was markedly less toxic than DDT dust even at the low dosage of

Table 1.—Mortality of honey bees caused by toxaphene, DDT, and chlordane applied before 7 a.m. to 5.2 acres of alfalfa in bloom, Logan, Utah, July–August 1950.

Insecticide	Dosage per Acre	Maximum Population Visiting Flowers on Day of Treatment	Estimated Kill of Field Force
	Pounds	*Number*	*Per Cent*
Toxaphene			
Spray	1.5	61296	0
Dust	1.7	33693	1
DDT			
Spray	0.5	25574	0
Dust	0.5	16643	10
Chlordane			
Spray	1.0	37752	19
		38970	8
Dust	1.0	33287	4

0.5 pound per acre, and results with chlordane were again variable. The three tests with chlordane in this series bring to eight the number of satisfactory tests made at a dosage of 1 to 1.25 pounds per acre. Of these tests, only one with dust and one with spray gave a kill exceeding 10 per cent. Variability has been a characteristic of results with chlordane, and this insecticide has tended to be the exception to the rule that dusts are more toxic than sprays.

In 1952 we turned our attention to more recently developed insecticides that growers were likely to use. Aldrin, heptachlor, malathion, and TEPP were tested at the most generally useful dosages (Table 2). When applied in the early morning, all these insecticides gave 10-per cent mortality or higher. The high kill obtained with 6 ounces of TEPP was rather surprising, although we had assumed earlier that this insecticide would have to be applied in the evening if damage to bees were to be minimized. An evening application was included to verify the assumption that it would be relatively harmless by the beginning of the flight period the next day. Even then the kill was 6 per cent of the maximum visiting population. At least part of this kill was the result of directly spraying late-foraging bees and does not necessarily indicate that the TEPP was still capable of killing bees 12 or more hours after application.

Table 2.—Mortality of honey bees caused by various insecticide sprays applied to 4.3 acres of alfalfa in bloom, Logan, Utah, August 1952.

Insecticide	Dosage per Acre	Maximum Population Visiting Flowers, day of Treatment	Estimated Kill of Field Force
	Ounces	*Number*	*Per Cent*
Morning applications:			
Aldrin	2	17746	10
Heptachlor	4	49235	26
Malathion	10	22734	46
TEPP	6	14900	63
Evening application:			
TEPP	6	31468	6

Although the mortality from any application of insecticide occurred largely within the first 24 hours and usually was nearly complete within 48 hours, the lethal effect of a few insecticides continued for a longer time. This was the case with dieldrin applied at 0.56 pound per acre in 1949; bees died for a week or more. In 1952 malathion gave a prolonged kill. Poisoned freshly killed bees were still recovered in small numbers after 4 days, when counts were discontinued. The 46-per cent mortality reported for malathion is therefore approximate but incomplete.

Table 3.—Mortality of honey bees caused by various insecticide sprays applied before 7 a.m. to 4.8 acres of alfalfa in bloom, Logan, Utah, August 1953.

Insecticide	Dosage per Acre	Maximum Population Visiting Flowers on Day of Treatment	Estimated Kill of Field Force
	Ounces	*Number*	*Per Cent*
Systox	6	22535	1
Endrin	4	39727	13
Aldrin	2	72019	22
Dieldrin	1	128008	36

In 1953 we tested Systox and endrin at dosages promising for control use, retested aldrin at 2 ounces per acre, and tried a much lower dosage of dieldrin than was used in 1949. Results of these tests are given in table 3. Only Systox gave a favorable result, killing but 1 per cent of the bees. Endrin, killing 13 per cent, probably deserves further testing as a bloom-period treatment, perhaps at a slightly lower dosage or as an evening application. The high kills with aldrin and dieldrin at low dosages rule them out as possible bloom-period treatments. The estimate for 1 ounce of dieldrin is probably minimum, since the field kill used was based on only the first 2 days of a 5-day

Table 4.—**Mortality of honey bees occurring at the hives and in the treated acreage when various insecticides were applied to alfalfa in bloom, Logan, Utah, 1950–53.**

Insecticide[1]	Dosage per Acre	Bees Dying as Result of Treatment		Kill Occurring in the Field
		At hives	In field	
	Pounds	*Number*	*Number*	*Per Cent*
Toxaphene	1.5	25	0	0
TEPP (P.M.)	0.38	1652	309	16
Aldrin	0.13	1374	464	25
Heptachlor	0.25	7861	4784	38
TEPP	0.38	3745	5709	60
Dieldrin	0.06	10384	35313	77
Malathion	0.63	317	10081	97
DDT	0.5	0	1649	100

[1] Except as noted, the applications were made before 7 A.M. DDT was applied as a dust; all other insecticides were used as sprays.

period of kill.

Early in these studies it appeared that the relative toxicity of insecticide treatments to honey bees could be reasonably well established by merely making daily counts of dead bees at the hives, provided the apiary was adjacent to the field so that most of the poisoned bees able to leave the field would reach the hives before becoming incapacitated. Furthermore many beekeepers and growers have the impression that a treatment has not harmed the apiary if dead bees have not accumulated in large numbers at the hives. Table 4 shows that there is little relation between the number of bees dying at the hives and the total kill. Therefore, field counts must be made to evaluate the toxicity to bees of a field application of an insecticide.

Throughout our studies we have noticed that most of the insecticides caused many bees to leave the field after initial contact for at least a few hours. This has been attributed to repellency, although it is recognized that poisoning by a sublethal dosage might cause affected bees to return to the hive until they have recovered. In 1953, 1.5 acres of seed alfalfa adjacent to the test field provided a reasonably good place to establish check stations to aid in the study of repellency on the treated acreage. The counts made in treated and check areas are presented in table 5. The check stations were not established until after the endrin had been applied.

A sharp decline in the visiting population occurred by afternoon on the days when endrin, aldrin, and dieldrin were applied. On the morning Systox was applied, the temperature did not fall below 70° F. and a small population was already in the field at 6. A.M. These visiting bees were hit by the Systox spray, and most of them left the field immediately. The population remained low all day, indicating that many potential visitors stayed away from the field in the morning as well as the afternoon. In all cases mortality accounted for only a small fraction of the population decline.

Repellency persisted until the afternoon of the day following spraying except when endrin was applied, when there was a temporary interruption in the morning of the second day. This insecticide was applied at the beginning of the flowering period when the amount of bloom was increasing rapidly and the flowers were most attractive. It is assumed that the field was un-

Table 5.—**Repellency to honey bees of field applications of insecticides, Logan, Utah, 1953.**

Insecticide	Date (August)		Minimum Temperature	Honey Bees Visiting Flowers on—				Decline Caused by Mortality
				Treated Area		Untreated Area		
	Applied	Bees Counted		A.M.	P.M.	A.M.	P.M.	
			Degrees F.	*Hundreds of Bees per Acre*				
Endrin	5	4	53	72	77	—	—	—
		5	48	83	21	—	—	8
		6	48	119	66	—	—	—
Dieldrin	12	11	45	189	234	218	368	—
		12	46	267	28	315	252	64
		13	47	46	211	155	—	—
Aldrin	19	18	66	181	153	116	155	—
		19	55	150	60	136	174	20
		20	53	56	140	111	150	—
Systox	26	25	46	106	109	73	63	—
		26	70	40	47	53	82	0.5
		27	60	62	90	77	82	—

usually inviting to the bees, and many visited the field only to be repelled again.

DISCUSSION.—To control insect pests of forage seed crops during the flowering period, one should first choose prebloom treatments that are most likely to avoid the necessity of later applications when the plants are in flower. If bloom-stage treatments cannot be avoided, wise selection of the insecticide is in order. Insecticides that show little toxicity to honey bees regardless of dosage, such as toxaphene, should be utilized wherever possible. When a potentially damaging treatment is necessary, it should be applied under conditions favoring minimum kill and the dosage should be kept as low as possible.

We have arbitrarily set a mortality of 10 per cent as the limit for sanction of a bloom-stage application. Naturally there is ample room on both sides of this limit for the use of judgment in particular cases. An important factor is the amount of bloom within foraging range of affected colonies that is treated at one time. Treatments interpreted as a little too toxic under our test conditions may not be prohibitive when there is ample untreated acreage in the vicinity.

In the initial report on these studies Todd *et al.* (1949) pointed out that the full seriousness to the beekeeper of treating fields in bloom may lie not in the percentage of bees killed but rather in the timing of the treatment in relation to the nectar flow. We are now even more convinced that this is true. A high kill of the field force sometimes does not appear to hurt a colony substantially, but the loss of the foraging population for a short period during a heavy nectar flow usually spells the difference between a good and a poor honey crop for the beekeeper.

Finally, it should be emphasized that the tests reported here do not shed much light on the damage to native species of bees serving as pollinators. One test, Bohart & Lieberman (1949), with 0.6 pound of DDT applied as a 3-per cent dust gave about 15-per cent mortality to a nesting aggregation of alkali bees, but the following year the population appeared to be normal. In another, unreported test under the same conditions an application of 2.3 pounds of toxaphene dust gave a comparable mortality. The danger of applying "across the board" the results of tests on one kind of bee was emphasized when a large cage that had been dusted with toxaphene and found safe to use with bumble bees was later used for a colony of *Melipona* with disastrous results.

SUMMARY.—In 1950, 1952, and 1953 tests were conducted to learn the effect of field applications of insecticides on honey bees. From 4.3 to 5.2 acres of seed alfalfa in bloom near Logan, Utah, were sprayed or dusted before 7 A.M. or after 7 P.M. The effect of each application on the field force of a small apiary placed at the edge of the field was measured by counting the dead bees at the hives and in the treated acreage.

In each test the dosage was one considered useful for controlling harmful insects on alfalfa in bloom. On the basis of 10-per cent mortality being the limit for sanction, the following treatments are considered as too toxic to honeybees: early morning sprays of TEPP 6 ounces, malathion 10 ounces, dieldrin 1 ounce, heptachlor 4 ounces, aldrin 2 ounces, chlordane 1 pound, and endrin 4 ounces, and an early morning dust of DDT 0.5 pound per acre. Treatments in addition to toxaphene classified as safe include morning sprays of DDT 0.5 pound and Systox 6 ounces, and an evening spray of TEPP 6 ounces per acre.

There was no relation between the number of bees dying at the hives and the number dying in the field. Most of the insecticides tested caused many bees to stay away from the field for at least a few hours following initial contact. Results of tests with honey bees do not necessarily apply to native bees.

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The Chromatography of Gyptol and Gyptyl Ester

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The isolation of pure gyptol, the sex attractant extracted from virgin female gypsy moths, *Porthetria dispar* (L.), and its characterization, beyond the fact that it is an alcohol, have presented a difficult problem owing mainly to the lack of an effective means for its quantitative estimation in the laboratory (Collins & Potts 1932, Haller *et al.* 1944, Acree 1953a).

This problem was partly solved when Acree (1953b) found that it was possible to adapt the procedure employing absorbancy ratios (Beroza 1950) to the chromatography of crude gyptyl azoate (*p*-phenyl-azobenzoyl ester) and, by this method for plotting the elution curve, showed that an active fraction of gyptyl azoate could be resolved into three active fractions of azoates and separated from an active fraction presumed to consist of free gyptol but now considered to have been the natural ester. During this work it became of interest to chromatograph the unsaponifiable fraction prepared from the benzene extractive of female moths in 1947, as described by Haller *et al.* (1944). All the activity was contained in the percolate, including the first yellow zone, that collected before the second yellow zone was eluted. This active fraction provided a highly purified starting material for the preparation of the azoates mentioned above.

Recently considerable progress has been made on this problem by using the wave lengths 228, 247, and 255 mμ, selected from the ultraviolet spectrum (curve 1, Fig. 1, Acree 1953b) of the free-gyptol fraction mentioned above, in the application of absorbancy ratios to the chromatography of the unsaponifiable fraction. The ultraviolet spectrum of the active zone separated from the first column by employing these wave lengths was similar to the preceding spectrum but had a maximum at 285 and a minimum at 249 mμ. Therefore, these wave lengths together with 230 mμ were used in subsequent experiments.

As a prerequisite to the use of this process, the solvent was purified sufficiently to allow the Beckman DU spectrophotometer to be balanced at 220mμ by passage through columns of silicic acid (Graff *et al.* 1944) and then distilled; the adsorbent was first washed and then equilibrated with the purified solvent.[1] The substance was introduced on the column as a concentrated solution, washed in, and then percolated with the solvent under a pressure of about 5 pounds of nitrogen per square inch. For the first one or two columns of the magnesium carbonate series, it was found necessary to stir a thin layer of the top of the column to prevent channeling. Material for rechromatographing was obtained from combined fractions of the eluate by removal of the solvent at reduced pressure.

Although many chromatographic columns were run in an effort to work out the most effective experimental details, only the most important experiments are described hereafter. The unsaponifiable fraction (47.7 mg. = 300 tips) was chromatographed on 20 g. of magnesium carbonate[2] with Skellysolve B. The eluate was collected in 5-ml. fractions up to the exit of the second yellow zone, and the absorbancy of each fraction was determined at 230, 249, and 285 mμ. The plot of these absorbancies against the respective fractions of percolate is shown in figure 1, of which zone B (2.3 mg.) was found to contain the active material.[3] It had been found in a preliminary experiment that the first yellow zone mentioned above was eluted between zones A and B, gave no interference at these wave lengths, and was eliminated on subsequent columns. The material from zone B was chromatographed on two more columns under these conditions, except that the fractions of eluate were reduced to 3 ml. Material B then amounted to 0.8 mg. Its elution curve from the third column is shown in figure 2, in which zone A was found to contain a trace of highly absorbing contaminant. More of B (91 mg. = 98,500 tips) was obtained by chromatographing

[1] For this and other suggestions made during the conduct of this work, the author thanks Morton Beroza.

[2] Special, low in chlorine, powdered C.P. magnesium carbonate, J. T. Baker Chem. Co., Phillipsburg, N. J.

[3] Field and laboratory tests of the attractiveness to male gypsy moths of the fractions from experiments described herein were made with the assistance of Ralph F. Holbrook, D. W. Mitchell, and D. J. Cyr in 1950–1953.

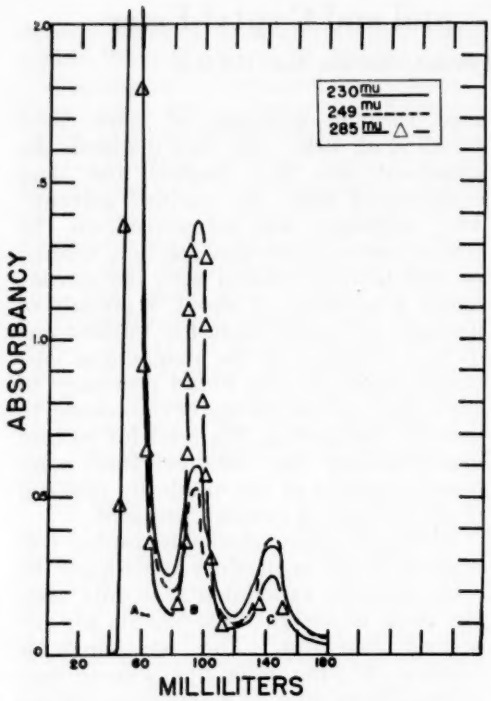

FIG. 1.—Elution curve of unsaponifiable fraction from magnesium carbonate. Zone B, active.

additional unsaponifiable fraction in 1-g. portions, together with that of partly purified active products recovered from previous experiments, through several 175-g. columns.

The lack of change in symmetry and threshold volume of zone B between columns 2 and 3 indicated that B was unchanged. However, difference in the absorbancy ratios 285/249 of the fractions around the curve indicated that the material was still a mixture, and another method for resolution was sought.

During earlier experiments the active material in the unsaponifiable fraction was found to have been eluted rapidly by a polar solvent from magnesium oxide absorbent[4] ahead of the first yellow zone. Therefore, material B (0.8 mg.) was chromatographed on 25 g. of this adsorbent with Skellysolve B in the hope of reversing and spreading the zone. No material was eluted in 500 ml. of this solvent, but it was found to have remained in the top two-fifths of the column, from which it was readily recovered with 5 per cent of absolute ethanol in Skellysolve B. This recovered material was used to work out experimental details, and then another lot of B equivalent to 900 tips was chromatographed on 30 g. of magnesium oxide with 0.3 per cent of absolute ethanol in Skellysolve B. This material yielded B1 through B5, the pattern of which is shown in figure 3. Additional quantities were obtained when B (91 mg. = 98.500 tips) was chromatographed on 100 g. of this adsorbent with 0.2 per cent of absolute ethanol in Skellysolve B. It is of interest to note the reversal of the wave-length ratios of zones B1 and B4; the combined fractions of each were later found to contain the active material. Materials from zones B2, B3, and B5 were found to be inactive.

In the meantime, B4 had been chromatographed with the solvent containing 0.25 per cent of ethanol and yielded B4A and B4B. B4B was found to be approximately one-third as active as B1, and was set aside for future study.

Since it now appears that a study of B4B will not be made, it seems desirable to point out the following observations.

[4] Hyflo Super-cel mixed 1:2 with adsorptive powdered magnesium oxide No. 2642, Westvaco Chlorine Products Co., Newark, Calif.

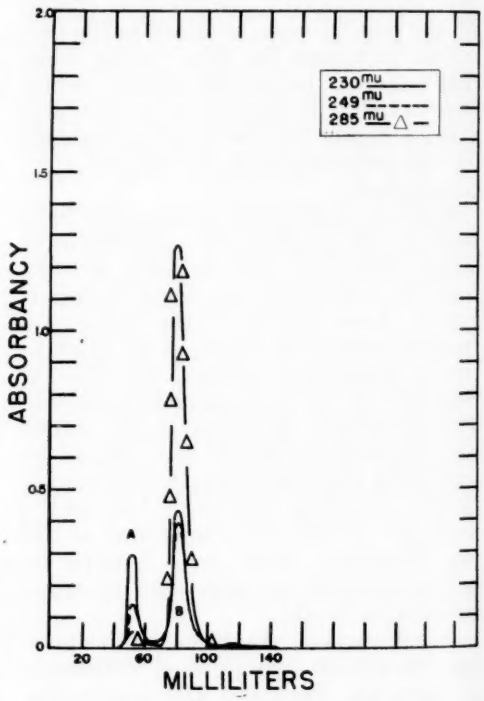

FIG. 2.—Elution curve of active material B from magnesium carbonate.

As is shown later, B1 was found to be an ester. Haller *et al.* (1944) and Acree (1953a) have proved the presence of free gyptol in the unsaponifiable fraction. Therefore, because the threshold volume of B4B was appreciably greater than that of B1, and because only B1 and B4B were attractive to male moths, B4B must be that free gyptol.The greater absorption at 285 mμ that occurs in zone B4B is not shown in the spectrum of gyptol B1A2A (Fig. 8) separated from B1, as described later. Although possibly due to contamination, this difference in absorption since B4B has been so highly purified, together with the greater rate of hydrolysis of its ester, seems to indicate that gyptol B4B may have an absorption curve different from that of gyptol B1A2A and is probably a primary alcohol.

All portions of B1 were combined and chromatographed on 100 g. of magnesium oxide with 0.2 per cent of absolute ethanol in Skellysolve B. The elution curve and the absorbancy ratios indicated a partial resolution of two products, B1A and B1B. Therefore, appropriate fractions of B1A were combined and rechromatographed twice to yield the elution curve shown in figure 4, the fractions of which were combined and designated as follows: 130–140 ml., B1A1 (6.0 mg.); 145–150 ml., B1A2 (17.5 mg.). Fractions 155–240 ml. were combined with appropriate fractions of B1B from the three columns and rechromatographed to yield the elution curve shown in figure 5, the fractions of which were combined and designated as follows: 135–165 ml., B1A2 (3.7 mg.); 170–175 ml., B1B1 (4.0 mg.); 180–250 ml., B1B2 (11.3 mg.).

Laboratory tests indicated that B1A1, both lots of B1A2, and B1B1 were attractive to male moths, but the more reliable field tests, made with 6 micrograms per trap, indicated that essentially all the active material of B1 was contained in B1A1 and B1A2. This low concentration attracted about the same number of moths as the unsaponifiable fraction tested at the equivalent of 30 females per trap. Therefore, the high specific activity of the gypsy moth sex attractant is clearly demonstrated. Since a part of the active material had already been removed as B4B, it was evident that at this stage the remaining active material of the unsaponifiable fraction had reached an extremely high concentration in B1A1 and B1A2, although their homogeneity was still uncertain.

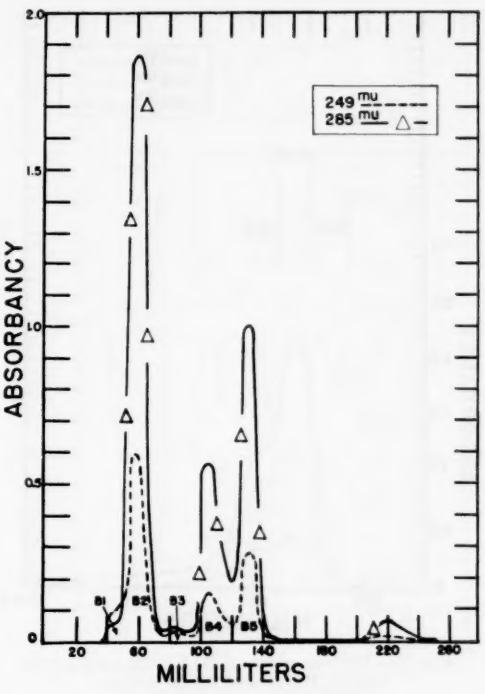

FIG. 3.—Elution curve of B from magnesium oxide. B1 and B4, active.

Because of the great affinity of B1A1 and B1A2 for Skellysolve B in adsorption chromatography, a search was made for partition solvents that could be used chromatographically in the ultraviolet, and for solvents and spray tests for use in paper chromatography; the results were essentially negative. Ascending paper-strip chromatograms made according to the general scheme of Williams & Kirby (1948) with solvent consisting of 12 parts of water: 7.8 parts of tert-butanol: 0.2 parts of ethyl acetate showed by the fluorescin-bromine-ultraviolet light test (Kirchner *et al.* 1951) that B1A2, but not B1A1, contained some B1B1. None of the spray tests usually applicable to the detection of unsaturation and hydroxyl groups positively identified zones of activity on paper chromatograms, although previously hydrogenation and esterification had indicated that gyptol was probably an unsaturated alcohol. Later, attempts to use countercurrent distribution (Craig 1944) and reversed-phase partition chromatography patterned after the work

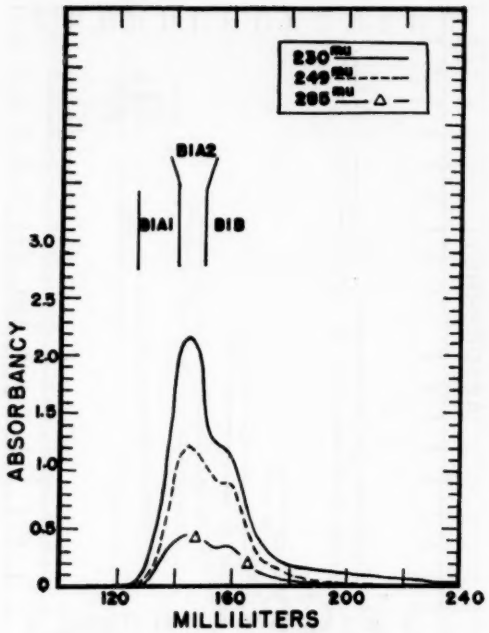

FIG. 4.—Elution curve of B1A from magnesium oxide, B1A1 and B1A2, active.

of Kritchevsky & Tiselius (1951) failed—in the first case because of inadequate solvents and in the second case because there was an excess of total absorbancy and a loss of material, although it was shown that active material could be eluted from the column.

The accumulated evidence indicated that B1A1 and B1A2 might be different products. Therefore, fractions of B1A1, B1A2, and B1B1 (Figs. 4 and 5) were combined to afford the maximum yield in the separation and concentration of products B1A1 and B1A2, and additional chromatograms were run on 100-g. columns of the magnesium oxide mixture with 0.05 per cent of absolute ethanol in the Skellysolve B. For some unknown reason, only a trace of material was eluted from the final column containing the fractions of B1A1, including those from figure 6, which, in addition, shows the elution curve of concentrated B1A2. This latter product amounted to 12.4 mg. (approx. 95,000 tips) and, although it crystallized in the icebox, it could not be recrystallized satisfactorily.

Laboratory tests of an unsprayed but sectioned paper chromatogram of B1A2, prepared as mentioned above, indicated two zones of activity. Their presence in B1A2 can be accounted for by its contamination with B1A1 and seems to indicate the possibility of B1A1 being a third gyptol. These two zones were more strongly indicated as follows: 2 g. (12,540 tips) of unsaponifiable fraction was chromatographed as already described through one column of magnesium carbonate and one column of magnesium oxide and yielded 35.2 mg. of crystalline product B1. A 25.6-mg. sample of this B1 was recrystallized from acetone; both the crystalline portion (14.6 mg.) and the oil (6.6 mg.) that was separated from the acetone mother liquor were found to be about equally active in field tests. In addition, 2.2 mg. of amorphous product was separated from the acetone mother liquor before its final concentration, but it was not tested for attractiveness.

Much of the puzzling behavior of B1A2, on the assumption that it was an unsaturated alcohol, was accounted for by a study of its infrared spectrum[5] and the almost identical spectrum shown in Figure 7 obtained from the crystalline portion of

[5] The infrared spectra included herein were prepared and interpreted by Jonas Carol, U. S. Food and Drug Administration.

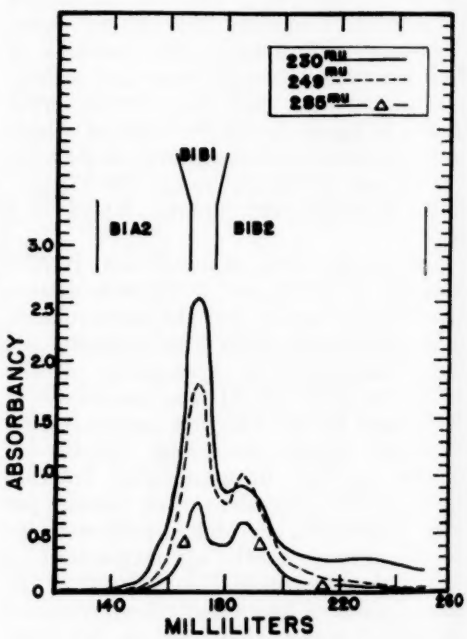

FIG. 5.—Elution curve of B1B from magnesium oxide. B1A2, active.

the freshly prepared B1. These spectra proved that B1 and B1A2 (and presumably B1A1) are long-chain esters; thus their great affinity for nonpolar solvents is accounted for.

The partition coefficient of B1A2 was determined on 11.4 mg. in a 1:1 mixture of carbon tetrachloride and absolute ethanol containing 30 per cent of formamide, and the recovered product (17.6 mg.) contained 6.2 mg. of contaminant.[6] In spite of this, the recovered product was saponified for 10 minutes with diethylene glycol-potassium hydroxide according to the procedure of Schneider (1946), modified by extraction of the neutral fraction with Skellysolve B prior to back-titration in order to prevent decomposition of gyptol by the mineral acid. The Skellysolve B solution yielded 3.1 mg. of neutral fraction B1A2A. The aqueous reaction mixture required 2.70 ml. of 0.02 *N* alkali, and the saponification equivalent was calculated to be 319. A crystalline acidic product, B1A2B (7.8 mg.), was separated

[6] After a 100-plate distribution of the 6.6 mg. of oil from B1 had been run, it was discovered that some reaction had occurred in this solvent mixture to produce a crystalline product which was not removed completely from the fractions by washing with water.

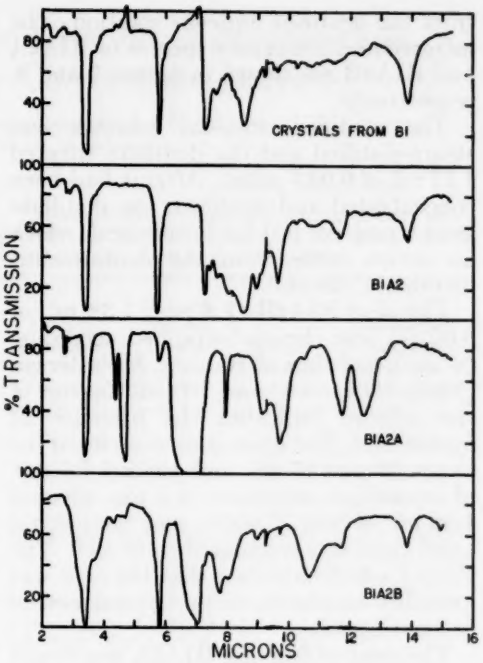

FIG. 7.—Infrared absorption curves of B1, B1A2, B1A2A, and B1A2B.

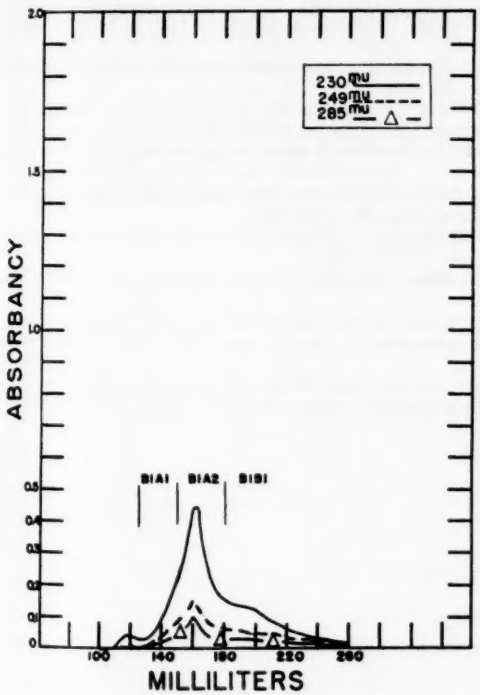

FIG. 6.—Elution curve of B1A2 from magnesium oxide.

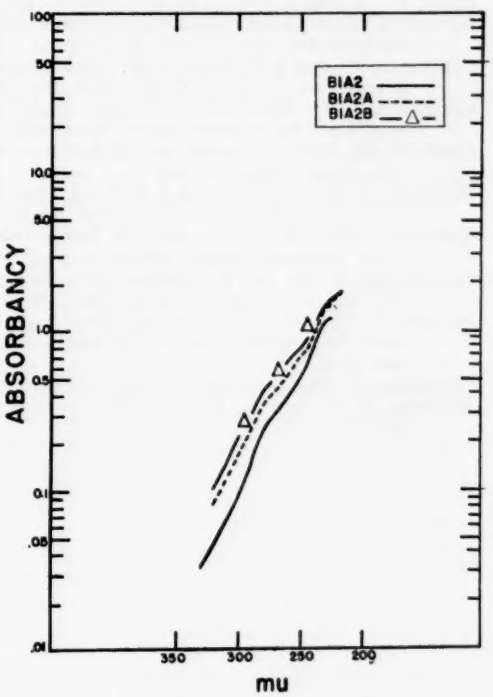

FIG. 8.—Ultraviolet absorption curves of B1A2, B1A2A and B1A2B. Solvent, absolute ethanol.

from the acidified aqueous solution. The infrared and ultraviolet spectra of B1A2A and B1A2B are shown in figures 7 and 8, respectively.

The acidified aqueous solution was steam-distilled and the distillate titrated 1.17 ml. of 0.02*N* alkali. After it had been concentrated and acidified, the distillate gave a positive test for formic acid, which no doubt came from the contaminant mentioned above.

The acid B1A2B (7.8 mg., 1.32 ml. of 0.02 *N*) was chromatographed according to the procedure of Ramsey & Patterson (1948). A narrow zone left at the top of the column indicated the presence of formic acid. The main zone was eluted between 19 and 65 ml. and yielded 7.5 mg. of crystalline substance; 6.4 mg. titrated 1.06 ml. of 0.02 *N* alkali, and the neutral equivalent was calculated to be 296. The Baeyer's test indicated that the acid was probably saturated, and it is presumed to be stearic acid.

The neutral fraction B1A2A was found to be attractive to male moths when tested in the laboratory. This material was obtained after a 10-minute saponification of B1A2, a reaction time found sufficient for complete saponification of esters of secondary alcohols by the procedure described above. Yet its ester, B1A2, was obtained after the original benzene extractive had been saponified with alcoholic potash for 17 hours, a reaction time normally sufficient to complete saponification of esters of primary alcohols. Therefore, B1A2A may be a secondary alcohol and therefore another gyptol different from gyptol B4B.

From the evidence described above it appears that a procedure has been developed which shows that the attractiveness of the gypsy moth sex attractant can be attributed to two, or possibly three, fatty esters derived from at least two different alcohols. Unquestionably the isolation should be repeated on fresh starting material in order to clarify some obvious points of uncertainty.

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Insecticide Concentrations and Timing of Applications for Control of the Clover Root Borer

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In an earlier paper, Gyrisco & Marshall (1950) reported excellent control of the clover root borer, *Hylastinus obscurus* Marsham, with applications of aldrin, dieldrin, and BHC dusts. Other workers, notably App & Everly (1950), have obtained similar results with formulations of aldrin, BHC and chlordane dusts. Information is lacking, however, on the minimum effective concentrations of these and other materials, on practical methods of timing such applications and on the use of these materials as sprays. Hence, work on the clover root borer during the past 4 years has been directed along these lines.

MATERIALS AND METHODS.—In 1950, a series of small plots were laid out in a replicated randomized complete block experiment so designed that a certain number of the plots would be treated in the fall, part of the other plots would be treated in the spring and the remainder of the plots would be treated both in the fall and in the spring. The fall treatments were made on October 15; the spring plots were treated on May 2, a date prior to adult activity. The fall-spring plots were treated on October 15 and again on May 19 the following year when the borer was at peak migration as determined by tanglefoot traps (Gyrisco & Marshall 1950). All the plots were treated at the rate of 1 pound of actual toxicant per acre of BHC, lindane, chlordane, aldrin and dieldrin. All the materials were used as dusts and were applied with a hand fertilizer spreader in a manner described in earlier papers. Hay samples for insecticide residue analysis were taken on June 8 of all the plots, but the results from the aldrin and dieldrin plots were so variable that they have been omitted from this paper. This great variability was believed to be due to the total chloride method of analysis for aldrin and dieldrin, an unreliable method for these materials but the only one known at that time.

During 1951, a series of four experiments, already described in detail by Gyrisco *et al.* (1952), were laid out in first harvest year stands of medium red clover. Aldrin, dieldrin, heptachlor and lindane were used in a graded series of

Table 1.—Treatments with insecticides to determine optimum timing for control of the clover root borer. Fulton, New York. October 1950.

DUSTS APPLIED[1]	WHEN[2] APPLIED	ROOTS UNINJURED	AVERAGE NO. ROOTS UNINJURED PER 10 SAMPLES	AVERAGE P.P.M. RESIDUE AT HARVEST (GREEN WEIGHT)
Aldrin	Fall	40	10.0	—
BHC[3]	Fall	40	10.0	0.19
Chlordane	Fall	40	10.0	0.0
Dieldrin	Fall	40	10.0	—
Lindane	Fall	40	10.0	(−)0.6
Aldrin	Spring	40	10.0	—
BHC	Spring	40	10.0	0.42
Chlordane	Spring	40	10.0	0.0
Dieldrin	Spring	39	9.7	—
Lindane	Spring	39	9.7	0.09
Aldrin	Fall & Spring	40	10.0	—
BHC	Fall & Spring	40	10.0	0.26
Chlordane	Fall & Spring	40	10.0	0.0
Dieldrin	Fall & Spring	40	10.0	—
Lindane	Fall & Spring	40	10.0	0.12
Untreated		34	8.5	—

L.S.D. at 5%—0.35
at 1%—0.49

[1] One pound active ingredient per acre.
[2] All fall treatments applied October 15, 1950. Spring only treatment applied May 19, 1951. Spring application of Spring-Fall treatments applied May 2, 1951. Hay samples taken June 8, 1951.
[3] Gamma isomer.

Table 2.—Treatments with aldrin at four concentrations for the control of the clover root borer. Fulton, New York. May, 1951.

ACTUAL TOXICANT PER ACRE[1] (POUNDS)	BORERS PER 40 ROOTS (ALL STAGES)[2]	ROOTS UNINJURED	ROOTS UNINJURED PER 10 SAMPLES (AVERAGE)
0.25	0	32	8.0
0.50	4	38	9.5
0.75	0	38	9.5
1.00	1	34	8.5
none	33	22	5.5

L.S.D. at 5%—2.1
at 1%—2.9

[1] Dusts applied May 15, 1951.
[2] Roots dug August 9, 1951.

[1] Now at the Arizona Agricultural Experiment Station, Mesa, Arizona.

[2] The authors acknowledge the assistance of Dr. R. H. Burrage, now of the Canada Department of Agriculture; W. G. Evans; and Dr. D. S. Marshall, now of California Spray-Chemical Company in part of the work reported in this paper.

Table 3.—Treatments with four concentrations of dieldrin for the control of the clover root borer. Fulton, New York. May, 1951.

Actual Toxicant per Acre[1] (Pounds)[2]	Borers per 40 Roots (All Stages)[3]	Roots Uninjured	Roots Uninjured per 10 Samples (Average)
0.25	10	34	8.5
0.50	2	39	9.7
0.75	5	39	9.7
1.00	2	38	9.5
none	22	31	7.7
		L.S.D. at 5%—1.4	
		at 1%—2.0	

[1] Dusts applied May 16, 1951.
[2] Harvested June 7, 1951; no insecticide residues reported (green forage).
[3] Roots dug August 10, 1951.

concentrations ranging from 0.25 pound to 1.25 pounds per acre (Tables 2, 3 & 4). Another experiment (Table 5) using parathion, toxaphene, methoxychlor and TDE was laid out, and the plots treated with 2 pounds of actual toxicant per acre. All the plots were treated on May 15, 16 and 17 or just prior to the peak of migration flight. Grass samples for analysis of the residues were taken on June 6 and 7 by cutting four 1-square-foot samples of standing hay at random in each plot, compositing the samples and stripping each green sample immediately of insecticide residues using the appropriate solvents. The parathion samples were analyzed by the Averell-Norris method (1948) while lindane and BHC were analyzed by the method of Tufts *et al.* (1950). Dieldrin and aldrin were analyzed by the total chloride method; heptachlor was analyzed from duplicate samples

Table 4.—Treatments with four concentrations of heptachlor for the control of the clover root borer. Fulton, New York. May, 1951.

Actual Toxicant per Acre[1] (Pounds)	Borers per 40 Roots (All Stages)[2]	Roots Uninjured	Roots Uninjured per 10 Samples (Average)	Average P.P.M. Residue at Harvest (Green weight)[3]
0.50	5	37	9.2	0.030
0.75	0	39	9.8	0.008
1.00	4	38	9.5	0.021
1.25	1	39	9.8	0.013
None	22	24	6.0	—
			L.S.D. at 5%—2.1	
			at 1%—3.0	

[1] Dusts applied May 16, 1951.
[2] Roots dug August 10, 1951.
[3] Harvested June 6, 1951; p.p.m. corrected for check.

Table 5.—Comparison of treatments with four organic insecticides for control of the clover root borer. Fulton, New York. May, 1951.

Material[1] (Dusts)	Borers per 40 Roots (All Stages)[2]	Roots Uninjured	Roots Uninjured per 10 Samples (Average)	Average P.P.M. Residue at (Green Weight)[3]
Parathion	3	36	9.0	0.7
Toxaphene	21	30	7.5	0.0
Methoxychlor	12	31	7.7	—
TDE	13	33	8.2	—
Untreated	23	29	7.2	—
		L.S.D. at 5%—1.2		
		at 1%—1.6		

[1] Treated May 17, 1951, with 2 pounds of actual toxicant per acre.
[2] Roots dug August 10, 1951.
[3] Harvested June 6, 1951; p.p.m. corrected for check.

retained until 1953 using an unpublished modification of the method of Polen & Silverman (1952) and earlier by the total chloride method.

In 1952, an experiment similar in design and size to those of the previous year was laid out in a good stand of first harvest year medium red clover and treated with four different dosages of lindane dust ranging from 1.0 to 1.75 pounds of actual toxicant per acre. The plots (Table 7) were treated with a hand fertilizer spreader on May 22, a date 3 to 7 days after a rather indefinite peak migration flight. In addition to this experiment, another field (Table 10) was divided into three large plots each 40 feet wide and 500 feet long. The center plot remained untreated while the other two plots were treated separately with emulsions of aldrin and lindane using 1 pound per acre of each insecticide. Both insecticides were applied with a low-pressure, low-gallonage weed sprayer using 40 pounds per square inch of pres-

Table 6.—Treatments with four concentrations of lindane for the control of the clover root borer. Fulton, New York. May, 1951.

Actual Toxicant per Acre[1] (Pounds)	Borers per 40 Roots (All Stages)[2]	Roots Uninjured	Roots Uninjured per 10 Samples (Average)	Average P.P.M. Residue at Harvest (Green weight)[3]
0.50	1	37	9.3	(−) 0.04
0.75	2	36	9.0	(−) 0.06
1.00	1	36	9.0	0.17
1.25	2	37	9.3	0.11
None	20	30	7.5	—
			L.S.D. at 5%—2.3	
			at 1%—3.2	

[1] Dusts applied May 17, 1951.
[2] Roots dug August 10, 1951.
[3] Harvested June 6, 1951; p.p.m. corrected for check.

Table 7.—Results of treatments with four concentrations of lindane for control of the clover root borer. Fulton, New York. May, 1952.

Actual Toxicant per Acre[1] (Pounds)	Borers per 40 Roots (All Stages)[2]	Roots Uninjured	Roots Uninjured per 10 Samples (Average)
1.00	7	18	4.5
1.25	12	18	4.5
1.50	3	23	5.7
1.75	1	22	5.5
None	75	15	3.7
		L.S.D. at 5%	−2.3
		at 1%	−3.2

[1] Dusts applied May 22, 1952.
[2] Roots dug August 6, 1952.

sure and 20 gallons of spray per acre. These plots were treated May 15, a date prior to the peak of beetle aerial migration.

During 1953, two dust experiments (Tables 8 & 9) identical in size and design as those of 1951 were laid out in a field of first harvest year, medium red clover and treated with 1 pound per acre dosages of isodrin, endrin, lindane, Test Material I,[3] heptachlor and dieldrin as well as with 2 pounds per acre of methoxychlor and parathion. All the dusts were prepared and were applied with a hand fertilizer spreader in a manner described previously (Gyrisco *et al.* 1950). In another large field of first cutting year medium red clover, two large plots 40 by 500 feet (Table 10) were laid out in the middle of a 12-acre field of clover and treated with 1 pound per acre of lindane applied as an emulsion at the rate of 20 gallons of spray per acre. All treatments were made on May 16 or prior to any clover root borer migration flights.

Table 8.—Results with four organic insecticides applied for the control of the clover root borer. Fulton, New York. May, 1953.

Material[1] (Dusts)	Active Toxicant per Acre (Pounds)	Borers per 40 Roots (All Stages)[2]	Roots Uninjured	Roots Uninjured per 10 Samples (Average)
Heptachlor	1.0	4	39	9.7
Dieldrin	1.0	4	38	9.2
Methoxychlor	2.0	34	25	6.2
Parathion	2.0	53	21	5.2
Untreated	—	97	16	4.0
		L.S.D. at 5%	−2.4	
		at 1%	−3.3	

[1] Treated May 16, 1953.
[2] Roots dug September 8, 1953.

Table 9.—Comparison of three new organic insecticides with lindane for control of the clover root borer. Fulton, New York. May, 1953.

Material[1] (Dusts)	Borers per 40 Roots (All Stages)[2]	Roots Uninjured	Roots Uninjured per 10 Samples (Average)
Isodrin	31	31	7.7
Lindane	65	25	6.2
Test material I	67	16	4.0
Endrin	133	10	2.5
Untreated	107	8	2.0
	L.S.D. at 5%	−2.6	
	at 1%	−3.7	

[1] Treated May 16, 1953, with 1 pound of actual toxicant per acre.
[2] Roots dug September 8, 1953.

In all of the dust experiments during the past 4 years, 40 roots were dug at random for each treatment (10 in each plot) in late summer. In the spray tests, a smaller total number of roots were chosen but a larger number of roots were examined per plot. While the location of the diggings was chosen in a random manner, only those roots exceeding 5 mm. in the lesser diameter at the crown were selected for examination since roots less than that size are not usually infested. Each root was then measured at the crown and carefully dissected to determine the presence or absence of clover root borers. Each root was recorded as infested or uninfested depending on the presence of galleries and/or any stages of the clover root borer. Whenever there was doubt as to the exact nature of the injury of any of the roots from the treated plots, they were scored as infested. The actual number of

[3] "NPD"-Tetra-n-propyl dithionopyrophosphate, E. I. du Pont de Nemours & Company, Wilmington, Delaware.

Table 10.—Results with low-volume, low-pressure sprays for the control of the clover root borer. Fulton, New York, (1952) and Oswego, New York, (1953).

Material[1] (Sprays)	Borers per 25 Roots (All Stages)[2]	Per Cent Uninfested
	1952	
Lindane	0	100
Aldrin	6	92
Check	30	72
	1953	
Aldrin	0	100
Check	39	30

[1] Treated May 15, 1952 and May 14, 1953, with 1 pound of actual toxicant per acre.
[2] Roots dug August 6, 1952 and September 8, 1953.

clover root borers of all stages was also recorded for each root.

In the late summer of the year following treatment, stand counts were made in some of the experiments by counting the number of old clover plants that could be found in 12 square feet in each treatment chosen in a random manner by throwing a wire frame enclosing 1 square foot into each plot.

DISCUSSION.—An examination of the results of the past 4 years shows that dieldrin, aldrin, heptachlor, isodrin, lindane, and BHC applied as dusts at the rate of 1 or more pounds per acre of actual toxicant have given excellent control of the clover root borer and good protection of the clover plants. Toxaphene, methoxychlor, TDE, Test Material I and parathion were erratic or unsatisfactory at the dosages at which they were used.

On the basis of these limited experiments, it would appear that the minimum effective dosage of dieldrin, aldrin and heptachlor as a dust is about 0.5 pound of actual toxicant per acre. Lindane, while sometimes successful, is usually erratic at this low dosage and a rate approaching 1 pound per acre is indicated. However, even with dieldrin, aldrin and heptachlor, one is apt to obtain more consistently good results if these insecticides are used at or near 1 pound per acre of actual toxicant. With such dosages, even a carelessly applied treatment could be expected to give satisfactory results. Work with dieldrin and heptachlor at the 1 pound dosage in 1953, when there was a heavy infestation of clover root borer, illustrates the excellent control of the borer and protection of the clover with such a practical dosage.

Isodrin in the one experiment in which it was used gave excellent control but endrin, in the experimental formulation available at that time, proved wholly unsatisfactory. More work with these two materials, however, is needed before one can draw definite conclusions.

It is rather obvious from table 1 that treatments for the clover root borer can be applied to new seedings either late in the fall or early the following spring. For best results in the spring, the applications should be made prior to the migration flight of the borer or at least prior to the peak of migration flight. Normally such applications in central and northern New York would be made sometime during the first 2 weeks in May. In 1952, the applications of lindane were applied after peak beetle flight and while they gave satisfactory control of the borers, they did not prevent root injury. Although the borers were either killed or forced to leave their galleries by the insecticide, their borings into the tap root provided excellent openings for the entrance of root rots and other disease organisms which caused the roots to be severely damaged by fall.

Fall application of insecticides have the obvious advantage of eliminating the problem of residues as the new growth the following spring has not been contaminated but under New York conditions, even applications in the spring do not present serious residue problems. None of the residues in any of the experiments were of such magnitude as to endanger grazing cattle or present the problem of milk contamination. Applications of insecticides in the fall are sometimes disadvantageous in that they come at a time when the dairy farmer is busiest with other activities such as fall plowing, planting of winter grains and making corn silage. In addition, some insecticides applied during a dry fall may deteriorate appreciably, and their potency in the spring may be insufficient to control the borer during its migration flight. While fall applications of insecticide have given good control, it is believed that applications in early spring are more practical and dependable year after year.

In preliminary tests low-gallonage sprays were successful. Although such applications can be made successfully, they were not as reliable as dusts for the control of the clover root borer. It is believed on the basis of these and other experiments not reported here that for best results with sprays one should apply 20 or more gallons of spray per acre, and such applications should not be made too early or too late in the spring.

In the plant persistence counts made in the heptachlor and dieldrin concentration experiments of 1951, there was a significant average increase of over 28 per cent in the stand of old red clover plants in all of the dieldrin plots as compared with the untreated checks, but no significant increases in stand in any of the heptachlor plots, although there was

an increase in the number of seedlings present. There is no question that lack of snow cover, winter heaving, poor agronomic practices, foliage and root diseases are important factors in reducing plant stand, and merely controlling the clover root borer will not guarantee clover persistence. Conversely, during years of mild winters, good snow cover, and the absence of the usual amount of foliage and root diseases, clover stands in experimental fields have been significantly increased as much as 39 to 71 per cent by control of the clover root borer (Newson 1948).[4]

SUMMARY.—During the past 4 years, spray and dust experiments using aldrin, dieldrin, heptachlor, isodrin, endrin, chlordane, toxaphene, methoxychlor, TDE, parathion, Test Material I, lindane and BHC were used in 11 different experiments to control the clover root borer.

It was found that although 0.5 pound per acre of aldrin, dieldrin, and heptachlor as dusts gave satisfactory control of the clover root borer, a pound per acre of actual toxicant seemed to be more practical and gave good results more consistently. One pound per acre of lindane, isodrin, chlordane and BHC as dusts also gave good control, but endrin, toxaphene, parathion, TDE and Test Material I gave unsatisfactory control at this and higher dosages.

Preliminary tests with aldrin and lindane applied as emulsions at the rate of 1 pound per acre of actual toxicant gave good control, but in general, sprays were less reliable than dusts. It was also found that at least 20 gallons of spray should be applied per acre for best results.

Plots sprayed both in the fall and the spring had no appreciable residue on the hay at harvest from either application. Fall applications, while giving good control of the insect and smaller insecticide residues on the hay, may not be practical from a grower usage standpoint as the fall season is often the busiest time in the year for the dairy farmer.

The applications of insecticide should be made prior to the flight of the adults yet late enough so the maximum amount of toxicant will be present around the crowns of the plants when the beetles arrive in their flights during migration.

Clover fields which have been properly managed and where diseases have not been a serious problem have shown significant increases in persistence of clover with clover root borer control.

[4] Newson, Leo Dale. 1948. The biology and economic importance of the clover root borer, *Hylastinus obscurus* (Marsham). Thesis for degree of Ph.D., Cornell Univ., 129 pages. Unpublished.

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The Persistence of Lindane-Chlorinated Terphenyl Residues on Outdoor Foliage[1]

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Laboratory tests have shown that mixtures of lindane and chlorinated terphenyl[2] leave filmlike residues that prolong the useful life of lindane severalfold (Sullivan & Hornstein 1953). In these films the volatilization rate of lindane is decreased by the reduction of its vapor pressure and also of the surface area available for evaporation per unit weight of lindane. In addition, the effectiveness of the residue is prolonged by the migration of lindane to the surface of the film (Hornstein & Sullivan 1953, Tsao *et al.* 1953).

This report is concerned with lindane-chlorinated terphenyl mixtures applied to foliage outdoors. Their effectiveness in different formulations has been studied, and an attempt has been made to measure the ease with which they are washed off the leaves.

Preliminary tests indicated that conventional types of formulations containing light and heavy oils were liable to burn foliage. Moreover, the residues from oil solutions of lindane-chlorinated terphenyl mixtures were not effective against house flies any longer than were those from lindane solutions. The sorption of oil solutions on leaves has been reported by Hadaway & Barlow (1949). Although such sorption might not affect the toxicity of the residue to chewing insects, it would materially alter the contact effectiveness of the insecticide.

To see if the solutions were readily absorbed, soluble dye was incorporated into lindane-chlorinated terphenyl solutions before they were applied to the foliage. Examination of a cross-section of a treated leaf under the microscope showed that the dye had penetrated into the cuticle when an oil solution was used. However, formulations with low-boiling solvents, such as acetone and methyl ethyl ketone, because of the rapid evaporation of the solvent, left a nonpenetrating residue, as indicated by the nonmigration of the dye into the leaf. They also showed no signs of burning, even on such tender foliage as young bean plants.

Although burning of foliage and loss of insecticide through penetration can be minimized by the use of low-boiling ketones as solvents, the resulting air-borne particles, because of rapid solvent evaporation, may not be useful for many purposes. High-boiling materials added to minimize this evaporation leave an undesired component in the lindane-chlorinated terphenyl deposit, which might affect its adherence and cause leaf penetration. The incorporation of water is of little help because of its high volatility. Moreover, when added to an acetone or methyl ethyl ketone solution, water will decrease the solubility of lindane and chlorinated terphenyl and may cause precipitation. However, this effect is minimized, if, instead of water alone, a fairly concentrated solution of a substance soluble in water but not in the organic solvent is added, and emulsions can be successfully prepared. Such a material will also lower the vapor pressure of the water, and thus its evaporation rate. More important, there will be little change in the size of the spray particles, because a nonvolatile nucleus is left as soon as some evaporation takes place. If this emulsion breaks rapidly after application, the water-soluble material will be readily removed by rain to leave the desired lindane-chlorinated terphenyl residue. Suitable for this purpose are either unstable emulsions or stable emulsions containing an emulsifying agent that rapidly decomposes after spraying, such as ammonium oleate.

The most promising noninjurious additives to water for this purpose are polyhydroxy compounds. The simplest of these compounds, ethylene glycol and glycerol, are too expensive for practical use. We have used an inexpensive, high-conversion corn syrup, sold as *Sweetose*.[3] This syrup contains 81.8 per cent of solids

[1] Presented at the meeting of the Eastern Branch of the Entomological Society of America at Philadelphia, Pa., Nov. 16–17, 1953.

[2] Available as Aroclor 5460 from Monsanto Chemical Co., St. Louis, Mo.

[3] Made by A. E. Staley Mfg. Co., Decatur, Ill.

Table 1.—Formulations of lindane, with and without chlorinated terphenyl, tested for persistence on foliage.

LINDANE 1 LB. PLUS THE INGREDIENTS LISTED	SOLUTIONS							SUSPENSIONS		EMULSIONS					
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11	No. 12	No. 13	No. 14	No. 15	No. 16
Chlorinated terphenyl:																
1 lb.				X		X	X		X	X	X	X	X			X
2 lb.		X						X								
Acetone to make:																
½ gal.								X								
1 gal.	X	X														
Methyl ethyl ketone to make:																
½ gal.			X	X	X	X			X		X	X	X			X
1 gal.							X									
No. 2 fuel oil ½ gal.			X	X												
Oil SAE 50 ½gal.+kerosene																
½ gal.					X	X										
Xylene:																
To make ½ gal.										X						
½ gal.														X	X	
Corn syrup+water:																
½ gal.+½ gal.								X								
½ gal.+½ gal.									X		X	X				X
Water:																
½ gal.										X			X			
1:1 by volume															X	
Triton X-100[1] 1½ oz.										X						
Emcol H-77:[2]																
½ oz.											X					
1 oz.													X			
7½ oz.												X				
Atlox 1045A[3] 2 oz.														X	X	
Ammonium oleate 1 oz.																X

[1] Alkyl aryl polyether alcohol.
[2] Blend of polyalcohol carboxylic acid esters and sulfonated oils.
[3] Polyoxyethylene sorbitol oleate-laurate.

and has a sugar-to-dextrin ratio of approximately 7:1.

In formulations containing lindane-chlorinated terphenyl, methyl ethyl ketone, and water plus corn syrup the water phase is the less volatile phase. It is therefore desirable to prepare oil-in-water emulsions. The emulsions with ammonium oleate are of this type. When methylene blue, a water-soluble dye, is added, a drop of the emulsion appears to be all blue. When DuPont oil red, an oil-soluble dye, is added, a drop of the emulsion contains discrete red particles. The blue (water) is therefore the continuous, and the red (oil) the discontinuous phase.

SPRAYING PROCEDURE.—Several of the formulations given in table 1 were sprayed on test plots containing four kinds of foliage. A continuous hand spray gun was used on plots of ornamental laurel and a spruce windbreak, and a mist blower on grass plots. Plots of elm and pine trees were treated with a carbon dioxide-propelled dispenser, which forces the liquid at a pressure of 100 p.s.i. through a Spraying Systems Co. model *Tee Jet* 1.27 atomizer nozzle to deliver a hollow-cone spray.

Table 2.—Per cent mortality of house flies exposed to heavy deposits of lindane and lindane-chlorinated terphenyl residues on laurel foliage.

FORMULATION NO.	TYPE OF SPRAY[1]	AGE OF RESIDUE (DAYS)		
		45	70	100
1	Solution	100	0	0
2	Solution	100	88	72
8	Suspension	100	88	87

[1] Applied on March 9, 1953.

BIOLOGICAL TESTS.—After the residues had aged for various periods, representative and roughly equal foliage samples were collected from the various plots and brought into the laboratory. Grass samples were cut at the base of the blades. The samples were placed in pint Mason jars with cheesecloth covers, together with 50 to 100 house flies (*Musca domestica* L.) 2 to 3 days old, temporarily immobilized with carbon dioxide. After the flies had been exposed for 30 minutes, they were transferred to cages and held for 24 hours for mortality determinations. The results are given in tables 2 to 5.

SPRAY-DEPOSIT DETERMINATIONS.—In the plots containing spruce, elm, and pine trees determinations were made of the spray deposits. Nine grams of DuPont oil red was added to each gallon of spray, and aluminum or glass plates 1 square

Table 3.—Per cent mortality of house flies exposed to lindane and lindane-chlorinated terphenyl residues on spruce foliage.

Formulation No.	Type of Spray[1]	Deposit, Mg./Sq. Ft.	Age of Residue (Days)				
			3	15	35	57	100
4	Solution	11	0	2	0.3	—	—
3	Solution	7	0	0.4	0	—	—
10	Quick-breaking emulsion	21	80	24.0	1	28	39
7	Solution	11	97	68	40	54	59

[1] Applied on May 12, 1953. (4 replications).

foot in area were set out in the plots. The deposit on each plate was washed with acetone into a 100 ml. volumetric flask, and the amount of dye in an appropriate aliquot of this solution was determined spectrophotometrically. Since the ratio of lindane to dye in the stock solution was known, the corresponding amount of lindane could readily be calculated. The results are shown in tables 3 and 5.

DETERMINATION OF EASE OF WASHOFF.—Another experiment was conducted to compare the ease with which the various formulations may be washed off the leaves. Treated elm leaves were allowed to dry on the plants for 24 hours, and then collected and placed in quart Mason jars containing 500 ml. of water. The jars were placed on a tumbling machine, which rotated at 60 revolutions per minute, for 45 minutes. The leaves were then taken out, the water was extracted with ether several times, and all ether layers were combined. The ether was evaporated and the residue taken up in acetic acid. Lindane determinations were made by the Schechter-Hornstein method (1952).

All the washed leaves were then individually dipped into each of two graduates containing 25 ml. of ether to remove the lindane. The ether extracts were combined, the ether was evaporated, and the lindane picked up in acetic acid and determined as before. The percentage of lindane washed off was then calculated as follows:

$$\frac{\text{Lindane in water} \times 100}{\text{Lindane in water} + \text{lindane on leaves}}$$

Table 4.—Per cent mortality of house flies exposed to lindane and lindane-chlorinated terphenyl residues on sprayed grass.

Formulation No.	Type of Spray[1]	Age of Residue (Days)			
		3	11	20	40
3	Solution	19	0	—	—
4	Solution	100	13	—	—
5	Solution	59	20	—	—
6	Solution	100	29	—	—
9	Suspension	100	—	91	6

[1] Applied on April 27, 1953.

Table 5.—Per cent mortality of house flies exposed to lindane and lindane-chlorinated terphenyl residues on elm and pine foliage. Sprays applied June 17, 1953.

Formulation No.	Type of Spray	Foliage	Deposit, Mg./Sq. Ft.	Age of Residue (Days)						
				1	3	7–9	15–17	22	44	79–85
11	Quick-breaking emulsion	Elm	12	100	—	96	—	55	41	54
		Pine	6	100	—	68	—	96	63	57
13	Quick-breaking emulsion	Elm	40	100	—	—	57	—	69[1]	70
		Pine	—	100	—	—	88	—	90[1]	67
14	Solution	Elm	11	100	—	33	—	2	0	—
		Pine	16	100	—	2	—	0	1	—
15	Stable emulsion	Elm	41	—	9	—	0	—	—	—
		Pine	12	—	0	—	0	—	—	—
16	Stable emulsion[2]	Elm	38	100	—	94	—	93	68	53
		Pine	21	100	—	97	—	88	96	48

[1] 38 days old.
[2] Emulsifying agent decomposes after application.

The percentages obtained with eight formulations are given below:

FORMULATION No.	TYPE OF SPRAY	PER CENT
1	Solution	56.0
2	Solution	0.2
8	Suspension	20.0
11	Quick-breaking emulsion	23.5
12	Stable emulsion	87.0
13	Quick-breaking emulsion	21.7
15	Stable emulsion	82.0
16	Stable emulsion[1]	27.0

[1] Emulsifying agent decomposes after application.

CONCLUSION.—Lindane-chlorinated terphenyl residues on outdoor foliage give longer protection than lindane alone. However, applications cannot be made from oil solutions, which tend to penetrate the leaf surface, or from stable emulsions, which are easily removed by wash-off. Effective applications from emulsions containing low-boiling ketones as the oil phase can be made if the water phase contains a fairly high concentration of a water-soluble material, such as a high-conversion corn syrup, and if either the emulsifying agent readily decomposes after application or an unstable emulsion is used.

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Organic Phosphorus Compounds as Toxicants in House Fly Baits[1]

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Studies by Thompson *et al.* (1953) in various sections of this country showed that good control of house flies, *Musca domestica* L., in dairy barns could be obtained with baits containing TEPP, lindane, an attractant, and water. The baits were applied with a garden sprinkling can to the floors of the barns, particularly where flies congregated in the greatest numbers. Gahan *et al.* (1953) demonstrated that similar baits with and without lindane greatly reduced the abundance of resistant flies in Florida dairies. They also found that satisfactory control could be obtained with aqueous solutions of sodium arsenate and an attractant exposed in metal pans. Under Florida conditions lindane did not improve the effectiveness of TEPP baits applied with a sprinkling can, but Thompson *et al.* found it very beneficial in their studies elsewhere.

Sodium arsenate and TEPP are more toxic to warm-blooded animals than is desirable for general use. The disposal of spoiled sodium arsenate baits is difficult because this toxicant is a stable water-soluble material and will therefore contaminate soil or water for a long time. TEPP baits present no disposal problem, but there is considerable danger in hand-

[1] Presented at the meeting of the Entomological Society of America, Los Angeles, Calif., December 7–10, 1953. This work was conducted at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine under funds allotted to the Bureau by the Department of the Army.

[2] The writers thank C. V. Bowen of the Orlando laboratory for his assistance; also T. B. Hester, P. H. Adcock, C. R. Crittenden, and H. B. Davis for performing many of the routine duties connected with this research.

ling the concentrated material.

Laboratory screening tests were undertaken during 1952–53 to find effective substitute toxicants for use in different types of baits. The most promising materials were malathion, Diazinon (*O,O*-diethyl *O*-2-isopropyl-6-methyl-4-pyrimidinyl thiophosphate), and Bayer L 13/59 (a dialkyl phosphonate). Malathion and Diazinon are commercially available in wettable powders and emulsifiable concentrates. Both have been tested extensively as residual treatments in barns in some areas, apparently with good results and without any ill effects to man or animals. L 13/59 is available only as a technical material in experimental quantities, but is readily soluble in water at concentrations needed in baits. Since all three compounds inhibit cholinesterase, care should be taken in using them.

During the summer of 1953 extensive field tests were conducted with these compounds in attractant baits for the control of resistant flies in dairy barns. This paper summarizes the results of laboratory and field tests with these materials.

LABORATORY STUDIES.—*Toxicity tests.*—Initial evaluations of the toxicants were made at concentrations of 0.5 and 2 per cent in 10 per cent aqueous solutions of malt or blackstrap molasses. Technical L 13/59 and laboratory-prepared emulsifiable concentrates of Diazinon and malathion were used in formulating the baits. Cotton pads 1 inch square were saturated with these baits and placed individually on top of small cylindrical screen-wire cages, where they could be fed upon by flies. Each cage contained 20 female flies from a highly DDT-resistant laboratory colony. After 16 hours the treated pads were removed and replaced with pads saturated with a honey solution. Mortality counts were made 1, 16 and 24 hours after the flies were given access to the baits. All three baits were highly effective, and so were tested further at concentrations ranging from 0.002 to 1 per cent. Two cages of 20 flies each were used in each test. The results are presented in table 1.

Diazinon and L 13/59 were more toxic than malathion, being highly effective at concentrations as low as 0.008 per cent. Malathion was slightly repellent at 1 per cent, but this was not apparent with the other materials. In previous tests malathion had shown greater repellency at this concentration.

Other tests were conducted to find out whether malathion and L 13/59 remain effective as long as 14 or 28 days after being prepared in liquid baits. Diazinon was not included in these tests. Stocks of baits containing 10 per cent of blackstrap molasses and the toxicant were prepared and stored at room temperature for periodical testing. To determine the length of time an emulsifiable concentrate would remain suspended in the molasses solution, the bait containing malathion was divided in half and one sample was stirred just before using whereas the other was never stirred. Since L 13/59 was completely soluble in water at the concentrations tested, it was assumed that it would remain equally dispersed in the bait without stirring. Periodically cotton pads 1 inch square were saturated at the surface of the stored baits and tested as previously described. Two cages of flies

Table 1.—Per cent mortality of house flies at different periods after they were given access to molasses baits containing various concentrations of malathion, Diazinon, and L 13/59.

Per Cent Concentration	Malathion			Diazinon			L 13/59		
	1 Hour	16 Hours	24 Hours	1 Hour	16 Hours	24 Hours	1 Hour	16 Hours	24 Hours
1.0	25	83	83	88	98	100	93	100	100
0.5	33	88	88	75	98	100	93	100	100
.25	48	88	88	50	90	93	98	100	100
.125	20	63	68	75	98	98	100	100	100
.063	23	70	70	45	100	100	50	85	90
.032	3	55	55	58	93	98	78	100	100
.016	3	38	40	68	90	90	50	88	93
.008	0	30	35	45	88	88	60	93	95
.004	3	15	23	0	18	18	40	80	80
.002	3	33	33	0	0	0	5	35	35

were used in each test. Mortality counts were made 24 and 48 hours after they were given access to the baits. The results are presented in table 2.

The bait containing L 13/59 remained completely effective after 14 days but was not tested thereafter. The stirred malathion bait was still as effective after 28 days as when freshly prepared, but the unstirred malathion bait showed some loss in effectivness. However, the reduction probably would be of little importance in practical use.

Acceptability tests.—Since flies will not feed on baits that are distasteful, a series of tests was run to determine the acceptability of 10 per cent molasses solutions containing various concentrations of malathion and L 13/59. Diazinon was not included in these tests. Pieces of filter paper were impregnated with 3 ml. of each formulation and exposed in uncovered 4-inch petri dishes in a room well-stocked with house flies. Each bait was tested against the standard, a 10 per cent molasses solution. Duplicate dishes containing a test formulation and the standard were arranged on a table in the shape of a square with the same treatments diagonal to each other. Eight counts of the flies landing on the papers were made at 1-minute intervals, the insects being disturbed and the dishes rotated one position to the right after each count. Each formulation was tested twice and the results averaged. The attraction ratio of the test bait to the standard was determined by comparing the numbers of flies landing on the respective baits. These ratios were as follows:

Per Cent Concentration	Malathion	L 13/59
1.0	0.13	0.78
0.1	.47	.89
.01	.84	.86

Malathion at a concentration of only 0.01 per cent caused a slight reduction in attractiveness, and higher concentrations were definitely repellent to flies. L 13/59 also showed a slight deleterious effect, but little difference between low and high concentrations.

FIELD STUDIES.—Practical tests were run in typical unscreened dairy barns in central Florida to determine the effectiveness of malathion, L 13/59, and Diazinon baits in controlling house flies under natural conditions. Two tests were made with TEPP for comparative purposes. Each bait contained one of these insecticides, an attractant, and water. Applications were made with a garden-type sprinkling can to the daytime feeding places of the flies in strips 4 to 6 inches wide. Most of the material was sprinkled on concrete floors, but in one dairy (No. 6) where an adjacent calf barn had dirt floors pieces of galvanized metal were placed between the pens and treated. Treatments applied to nonabsorbent surfaces were more available to the insects and therefore much more effective than those applied to dirt or litter-covered floors. From 1 to 3 gallons of bait were used for each treatment, depending on the floor area of the dairy. Applications usually were made 5 days each week (Monday through Friday) for 3 to 5 weeks, after the cows had been milked in the morning.

The abundance of house flies was determined by counting the flies that alighted on a piece of hardware cloth laid over two petri dishes partially filled with equal parts of malt and water. The dishes were always exposed in the locations where the density of flies was greatest. Five counts were made daily for 3 days before the bait treatments were started and 5 to 6 days each week thereafter. Counts were continued after completion of the tests in order to follow the restoration of the fly population. The degree of control was based on the difference in the count of

Table 2.—Per cent mortality of house flies after feeding on molasses baits containing malathion or L 13/59 at various intervals after preparation.

Days After Preparation	Hours After Feeding Was Begun	Malathion 0.5%		L 13/59	
		Stirred	Not Stirred	0.016%	0.004%
1	24	55	63	100	92
	48	90	95	100	92
4	24	93	75	—	—
	48	100	98	—	—
7	24	—	—	100	100
	48	—	—	100	100
14	24	90	78	100	100
	48	98	90	100	100
28	24	90	70	—	—
	48	100	85	—	—

flies before and at intervals after treatment. Dairies in which no fly control was practiced were not available. Results of these tests are summarized in table 3.

Five applications per week of the bait containing 0.1 per cent of malathion and 10 per cent of molasses produced excellent control of flies in dairy No. 1. The same bait applied three times a week failed to give satisfactory control in dairy No. 2, but 86 to 89 per cent control was obtained the second and third weeks of the test with five applications per week. The control in this barn apparently was affected by an adjoining open calf barn with a dirt floor. The floor of this building was littered with straw mixed with manure, which was so attractive to the flies that many of them ignored the bait exposed on pieces of galvanized metal between the pens.

Lowering the molasses content to 3

Table 3.—Effectiveness of baits applied with sprinkling cans for the control of house flies in open dairies.

Per Cent of Toxicant	Per Cent of Attractant	Dairy No.	Number of Applications per Week	Per Cent Daily Reduction	
				Range	Average
Malathion 0.1	Molasses 10	1	5	96–98	97
			5	99	99
			5	92–99	98
			1	93–99	97
			0	66–90	78
	Molasses 10	2	3	60–78	70
			5	71–97	86
			5	78–95	89
			0	18–95	55
	Molasses 3		6	15–83	45
			5	30–70	56
			5	78–87	82
	Corn syrup 3	3	5	91–98	96
			5	85–95	92
			5	95–98	97
L 13/59 0.1	Molasses 10	7	5	88–99	94
			5	93–98	96
			5	98–99	99
	Sugar 10	8	5	86–98	95
			5	97–99	98
			5	98–99	99
.02	Sugar 3	5	5	69–87	83
			5	76–95	85
	Molasses 10		5	94–98	96
			5	91–99	94
			5	90–98	94
.01	Sugar 3	4	5	25–91	61
	10		5	78–99	91
			5	93–99	97
			5	86–96	90
	Sugar 3	6	5	29–67	52
	Corn syrup 3		6	29–79	46
	10		6	46–97	78
			5	94–98	97
			5	95–99	97
Diazinon .1	Sugar 10	14	5	95–100	97
			5	84–99	96
			5	99–100	99+
TEPP .1	Molasses 10	3	5	74–96	84
			5	49–91	77
			5	67–91	79
.05	Molasses 10	1	4	67–86	79
			5	14–97	74
			5	48–97	80

per cent apparently reduced the effectiveness of 0.1 per cent of malathion somewhat, for the bait gave considerably less control than in the dairy with 10 per cent of molasses. However, a bait containing 3 per cent of corn syrup was highly effective in dairy No. 3.

An effort was made to test 0.01 per cent of malathion plus 3 per cent of molasses in another dairy, but after the second treatment the owner became dissatisfied with the results and applied a TEPP bait. Only 28 and 34 per cent reductions were obtained with the two applications.

Baits containing 0.1 per cent of L 13/59 and 10 per cent of molasses or sugar were highly effective in two dairies, giving average weekly controls of 94 to 99 per cent over a 3-week period.

Concentrations of only 0.01 and 0.02 per cent of L 13/59 with 3 to 10 per cent of various attractants were less effective than 0.1 per cent of L 13/59 the first week, but repeated treatments eventually gave effective control in three locations. Improved control was obtained in one dairy (No. 5) within 24 hours after the attractant was changed from 3 per cent of sugar to 10 per cent of molasses. A similar improvement resulted in another dairy (No. 4) when the sugar content of the bait was increased from 3 to 10 per cent. Poor control was indicated in a third dairy (No. 6) throughout the first 2 weeks with baits containing 0.01 per cent of L 13/59 and 3 per cent of sugar or corn syrup. When the syrup was increased to 10 per cent the third week, the control gradually increased and during the fourth and fifth weeks averaged 97 per cent. In spite of the unsatisfactory results obtained during the first and second weeks in dairy No. 6, dead flies were numerous on the floor each day within 10 minutes after the bait was applied and counts made after 30 minutes always showed between 95 and 99 per cent reductions. Collections of dead flies on the floor ranged between 15,000 and 66,000 the second week of treatment and reached 121,000 on one occasion the third week. During the fourth week collections never exceeded 5,000 and were therefore discontinued.

Excellent control was obtained in dairy No. 14 with 0.1 per cent of Diazinon (wettable powder) plus 10 per cent of sugar. The fly population was reduced 99 per cent within 24 hours after the first application, and the control averaged above 96 per cent throughout a 3-week test period.

Standard baits containing 0.05 or 0.1 per cent of TEPP and 10 per cent of molasses did not provide as good control as most of the experimental baits.

In the course of these tests it was observed that baits containing 0.1 per cent of malathion, L 13/59, or Diazinon gave exceptionally quick reductions of existing fly populations. Dead flies could be found within 5 minutes after feeding started. In several dairies counts indicated reductions of 90 per cent or more within 30 minutes and up to 98 per cent within 3 hours. Frequently similar reductions were also indicated 24 hours after treatment, but at other times considerable numbers of flies were again present. The variations in the 24-hour reductions apparently reflected differences in breeding pressure and adult-fly emergence on the premises and did not necessarily mean that similar treatments were less effective initially in the various locations. However, the differences indicated that more frequent treatments are necessary to achieve control in locations where breeding pressure is great. Results indicated that daily treatments for about 2 weeks will reduce the breeding potential in most locations to a point where treatments 2 to 4 times a week will maintain satisfactory control.

Early in the summer of 1953 the Sanitation Department of the city of Orlando, Fla., requested advice and assistance in controlling house flies in a large garbage-disposal area where repeated sprayings with lindane and other insecticides had proved almost completely ineffective. A survey of the area revealed heavy breeding in improperly processed garbage and an enormous adult population. Flies from the area were migrating into nearby residential areas, and homeowners insisted upon immediate remedial measures.

Under the supervision of the authors a bait consisting of 0.1 per cent of malathion and 10 per cent of blackstrap molasses in water was prepared and 15 gallons sprinkled on top of this refuse. An attempt was made to cover it completely. The initial treatment caused an estimated 75 per cent reduction in the adult-fly population within 24 hours. Daily treatments at rates of 12 to 15

gallons for a week reduced the adult population to a low level, and thereafter above 95 per cent control was maintained with 9 to 12 gallons per day. The results obtained in this area indicate that baits properly applied can be relied upon to provide control of house flies under adverse conditions. It is therefore believed that such baits will prove a useful adjunct to sanitation and other measures usually employed in community fly-control programs.

SUMMARY.—Laboratory and field tests were run to evaluate malathion, Diazinon (*O,O*-diethyl *O*-2-isopropyl-6-methyl-4-pyrimidinyl thiophosphate), and Bayer L 13/59 as bait toxicants against adult house flies, *Musca domestica* L. In laboratory studies against DDT-resistant flies Diazinon and L 13/59 were more toxic than malathion in an aqueous solution containing 10 per cent of molasses. L 13/59 reduced the attractiveness of baits slightly and certain concentrations of malathion markedly reduced their acceptibility. Liquid baits containing these two toxicants remained highly toxic after standing 14 days.

Practical tests were run in dairies by sprinkling the baits on the floors and other locations where flies congregated. Single applications of baits containing 0.1 per cent of malathion, Diazinon, or L 13/59 and 10 per cent of attractant caused excellent immediate reductions of existing fly populations, but frequent retreatments were necessary to maintain a high level of control. Concentrations of only 0.01 and 0.02 per cent of L 13/59 were less effective initially than 0.1 per cent, but repeated treatments gave effective control in 1 to 3 weeks. Baits containing 10 per cent of molasses or sugar appeared to be superior to those with only 3 per cent of these attractants or corn syrup. Standard baits consisting of 0.05 or 0.1 per cent of TEPP in a 10 per cent molasses solution did not provide as good control as most of the baits containing malathion, Diazinon, or L 13/59.

A bait containing 0.1 per cent of malathion and 10 per cent of molasses in water provided highly effective control of flies in a garbage-disposal area where sprays of lindane and other insecticides had proved ineffective.

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ERRATA

Volume 47, No. 1, page 165, first line of article by Walter E. Fleming and Warren W. Maines should read as follows:

"Chlordane at the rate of 10 pounds per"

Laboratory Tests for Control of Wireworms[1]

WALTER M. KULASH[2] and R. J. MONROE[3]

Numerous laboratory tests have been planned by the authors for the purpose of determining an effective method for controlling wireworms attacking corn. One of these methods, seed coating, has been described in an earlier paper (Kulash 1953). The present paper is a description of some other methods and materials used, a summary of the results obtained, as well as a comparison of the efficiency of the different methods of control.

METHODS AND MATERIALS.—Thirteen different materials[4] used in the laboratory tests described in this paper were as follows: aldrin, chlordane, dieldrin, endrin, di (para-ethyl phenyl) dichloroethane, heptachlor, lindane, parathion, pentachlornitrobenzene, potassium ethyl xanthate, two nitroparaffin compounds, 2-nitro-1, 1-bis (p-chlorophenyl) butane, and 2-nitro-1, 1-bis (p-chlorophenyl) propane, and demeton.

These materials were used in one or more of three different methods of application, i.e., as a seed coating, a soil treatment, or mixed with fertilizer.

For coating seed, wettable powder concentrates were used mixed with 5 per cent methylcellulose,[5] a water soluble sticker. An even distribution of the seed coating was obtained by vibrating the seed in a paint-reconditioning machine for 3.5 minutes immediately after the mixture had been applied to the seed. Seed coating materials used are listed in table 1.

Five treated seeds were planted at a depth of 2 inches in cans of sterilized peat muck soil collected in eastern North Carolina in an area where wireworms severely attack corn. Five full-grown wireworms collected from the same area were added to each can after planting. Five cans 7 inches deep and 6 inches in diameter (No. 10 size), were used for each material tested.

The second method of laboratory testing consisted of treating the soil but not the seed. Four tests were conducted according to this method. In two tests, No. 10 cans with five untreated corn seeds and five full-grown wireworms per can were used, each treatment replicated five times. Most of the toxicants used in these two tests were wettable powder concentrates diluted to the desired strength with inert talc. To make applications uniform, the desired amount of toxicant was applied as a finished dust at the rate of 10 grams per can of soil. Soil and insecticide were thor-

Table 1.—Summary of seed treatments for wireworm control in corn.

Formulation Used	Grams of Insecticide per 450 Grams of Seed	Per Cent	
		Wireworms Killed[1]	Plants Damaged[1]
25% aldrin	4.56	48	0
25% aldrin	2.28	75	0
25% aldrin	0.566	30	0
25% dieldrin	4.56	52	0
25% dieldrin	2.28	33	0
25% dieldrin	0.566	46	0
25% heptachlor	4.56	54	0
25% heptachlor	2.28	37	0
25% lindane	2.3	38	0
75% lindane	0.614	52	0
15% parathion	4.56	21	0
50% chlordane	4.56	17	0
50% DDT	4.56	0	26
75% DDT	4.56	8	32
50% 2-nitro-1,1-bis (p-chlorophenyl) propane	4.56	8	68
50% 2-nitro-1,1-bis (p-chlorophenyl) butane	4.56	0	72
50% di (para-ethyl phenyl) dichloroethane	4.56	0	36
20% pentachlornitrobenzene	4.56	0	60
Inert clay	4.56	0	84
Untreated	0	0	80

[1] Eight days after treatment and planting.

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[5] Prepared from Methocel, a 15 centipoise viscosity water-soluble cellulose ether supplied by the Dow Chemical Co., Midland, Mich.

Table 2.—Results of soil treatment Test No. 1 for wireworm control in corn 8 days after treatment and planting.

Insecticide	Pounds Toxicant per Acre	Per Cent Wireworms Killed	Per Cent Plants Damaged by Wireworms
Heptachlor	2	65	16
Lindane	2	12	44
Aldrin	1	12	52
Parathion	10	10	68
Parathion	5	0	72
Chlordane	10	0	44
Chlordane	5	0	72
DDT	25	0	72
Untreated	0	0	84

Kill Criteria

$\chi_8^2 = 71$, P = .001

Omit check, $\chi_7^2 = 15$, P = .04

Injury Criteria

$\chi_8^2 = 37$, P = .001

Omit check, $\chi_7^2 = 17$, P = .02

Omit check and heptachlor, $\chi_6^2 = 11$, P = .09

oughly mixed by shaking in a small hand-operated mixing drum for 5 minutes. Materials used in the first test by this method are listed in table 2.

The second test in treated soil was not run at the same time as the first nor did it have an equal number of replications. The materials used were di(para-ethyl phenyl) dichloroethane, pentachlornitrobenzene, and potassium ethyl xanthate. The last-named material, on being mixed with acids is reported to release carbon disulfide slowly. It was first premixed with superphosphate and sulfur before mixing with the soil. A summary of the results obtained in this test is presented in table 3.

Two other tests with treated soil were conducted in 3-ounce pill boxes with one untreated oat seed and one full-grown wireworm per box, each replicated 10 times. In these tests, (tests 3 and 4) liquid formulations of insecticides were used instead of dust formulations. Sterilized peat muck soil was spread over an area 12 inches square to a depth of 1 inch and then sprayed with 10 ml. of fluid containing the desired amount of toxicant, estimated to be equivalent to 50 gallons per acre. The soil was stirred during the spraying and immediately after in order to insure a more thorough wetting of the soil. The insecticides used in these two tests are listed in table 4.

In the third method of treatment, the insecticide was mixed with fertilizer and applied to the soil at the planting level of corn in No. 10 cans. Wettable powder concentrates were diluted with inert dust and mixed with a 6-8-6 fertilizer in the proportion of 1:1. The required amount of toxicant per can was contained in 2 grams of such a mixture. One gram of this insecticide-fertilizer mixture was applied to the surface of the soil and five seeds per can were then placed at the same level and covered with a 0.5 inch layer of untreated soil. Another gram of the insecticide-fertilizer mixture was applied at this level and covered with a 1-inch layer of untreated soil. Five full-grown wireworms were then added to each can. Each treatment had 5 cans or replicates. The results obtained by this method of treatment are listed in table 5.

After each test was set up, it was maintained and observed in a standard manner. All cans and pill boxes were kept in a heated laboratory where the room temperature averaged 74° F. Each test was conducted separately. Treatments and replications within each individual test were completely randomized in their arrangement in the laboratory. Soil in the cans was watered when necessary in order to avoid excessive drying.

Wireworms used in all laboratory tests were collected in muck soil in eastern North Carolina a few days before each test. All tests were conducted with a single

Table 3.—Summary of soil treatment Test No. 2 for wireworm control in corn 8 days after planting and treatment.

Material	Pounds per Acre	Per Cent Kill of Wireworms	Per Cent of Plants Damaged by Wireworms
Di (para-ethyl phenyl) dichloroethane	50	0	40
Pentachlornitrobenzene	20	0	80
	40	0	0
	100	0	80
Potassium ethyl xanthate plus superphosphate	500 500	60	0
Potassium ethyl xanthate plus superphosphate	500 1000	10	0
Potassium ethyl xanthate plus superphosphate plus sulphur	500 500 250	40	0
Potassium ethyl xanthate plus superphosphate plus sulfur	500 1000 250	60	0

Table 4.—Summary of soil treatment tests 3 and 4 for wireworm control in oats 8 days after treatment and planting.

Treatment	Pounds Toxicant per Acre	Per Cent Wireworms Killed			Per Cent Plants Injured		
		Test 3	Test 4	Average	Test 3	Test 4	Average
Heptachlor	2	100	100	100	0	0	0
Lindane	2	100	100	100	0	0	0
Dieldrin	2	75	89	82	10	20	15
Aldrin	2	100	70	82	0	40	20
Chlordane	4	56	33	44	10	50	30
Endrin	2	14	0	7	50	90	70
Demeton	0.25	20	33	26	60	100	80
Untreated	0	10	10	10	70	100	85
	χ_7^2=38.1		45.2	79.8	33.1	50.4	75.2
	P=<.001		<.001	<.001	<.001	<.001	<.001

species of wireworm, *Melanotus communis* (Gyll.), which has been very destructive to corn in eastern North Carolina.

RESULTS.—The efficacy of the different methods of control was based on two criteria—(1) injury to plants by wireworms and (2) kill of wireworms. Daily post-treatment examinations were made of each treatment to observe any wireworm activity on the soil surface. Condition of the plant foliage was noted at the same time. A final observation of each can at 8 or 9 days after planting included examination of the soil, roots, stems, and wireworms. Plants were about 6 to 8 inches high at the final examination.

Table 5.—Summary of tests with insecticide-fertilizer mixtures for wireworm control in corn 8 days after treatment and planting.

Insecticide	Pounds Toxicant per Acre	Per Cent Wireworms Killed	Per Cent Plants Damaged by Wireworms
Heptachlor	1	28	32
	2	84	0
	5	76	0
		χ_2^2=21.0, P=.001	χ_2^2=17.8, P=.001
Aldrin	1	63	12
	2	52	24
	4	54	28
		χ_2^2=0.57, P=.78	χ_2^2=2.10, P=.34
Parathion	5	52	20
	10	28	32
	20	68	16
		χ_2^2=8.16, P=.016	χ_2^2=1.95, P=.37
Lindane	2	25	8
	4	64	28
		χ_1^2=7.54, P=.006	χ_1^2=3.38, P=.07
Dieldrin	1	16	12
	2	26	20
	4	33	60
		χ_2^2=1.97, P=.36	χ_2^2=15.5, P=.001
Chlordane	5	21	44
	10	12	16
		χ_1^2=.31, P=.38	χ_1^2=4.67, P=.03
DDT	25	0	48
Check	0	4	68
		χ_1^2=1.00, P=.35	χ_1^2=2.06, P=.11

Wireworms were noticed on the soil surface of a few cans in the daily post-treatment observations. In general, only a few wireworms came to the soil surface and died. Daily measurements of height of corn as well as of its general condition showed no effects that could be ascribed to the action of the insecticides. At the final count, each can was emptied and the condition of the wireworms was recorded. In addition, a careful examination was made of the roots and stems of the plants to determine the nature and amount of wireworm damage or injury possibly caused by the insecticide.

The results of the seed coating trials with 20 different treatments are summarized in table 1. From the standpoint of wireworm injury to plants little protection to corn was afforded by the following materials: DDT, di (para-ethyl phenyl) dichloroethane, 2-nitro-1 1-bis (p-chlorophenyl) butane, 2-nitro-1, 1-bis (p-chlorophenyl) propane, and pentachlornitrobenzene. All the other materials gave good protection. An analysis of the kill data shows about the same thing. DDT and the other compounds mentioned above produced low percentages of kill, whereas

Table 6.—Comparisons of the most effective methods of treatment with insecticides for control of wireworms in the laboratory.

Material	Per Cent Wireworms Killed by Method of Treatment					Per Cent Wireworm Damage to Plants by Method of Treatment				
	Seed-Coating	Soil-Treatment		Insecticide-Fertilizer	Average	Seed-Coating	Soil-Treatment		Insecticide-Fertilizer	Average
		With Corn	With Oats				With Corn	With Oats		
Heptachlor	54	65	100	84	76	0	16	0	0	4
Lindane	52	12	100	64	57	0	44	0	28	18
Aldrin	75	12	82	63	58	0	52	20	12	21
Dieldrin	52	—	33	27	37	0	—	15	60	25
Chlordane	17	0	44	21	20	0	44	30	44	29
DDT	8	0	—	0	3	32	72	—	48	51
Check	0	0	10	4	3	80	76	85	64	76
	48[1]	18	72	43		5[2]	46	13	32	

[1] Average per cent kill by methods (excluding checks).
[2] Average per cent damage by methods (excluding check).

the remaining compounds had kills ranging from 17 to 75 per cent.

Larger dosages of the same insecticide as a seed coating did not produce a correspondingly greater kill of wireworms. Aldrin 25 per cent, at 2.28 grams per 450 grams of seed, produced a much higher kill of wireworms, 75 per cent, than it did at a dosage of 4.56 grams, with a kill of 48 per cent. A similar condition was noted in the case of 25 per cent dieldrin, which at 0.566 grams per 450 grams of seed produced a kill of 46 per cent, whereas at 2.28 grams, it killed only 33 per cent.

Chlordane and parathion, although they produced a relatively low kill of 17 and 21 per cent, respectively, nevertheless afforded good protection to the seed at the dosages used.

In the first treated-soil test with corn, heptachlor was the only material to show any great effect as far as kill was concerned. All other materials were slightly better or about the same as the untreated check (Table 2). The injury criterion showed some differences among the treatments in this test. Heptachlor gave the best protection with only 16 per cent of the plants damaged by wireworms while the untreated check had 84 per cent of the plants damaged. Chlordane at 10 pounds per acre and lindane at 4 pounds per acre had less damage than the other compounds. However, if either lindane or chlordane is omitted from consideration, the evidence to support the effectiveness of the other is not so conclusive. (See table 2, $\chi_6^2 = 11$, $P = .09$).[6]

Corn planted in treated soil developed in a normal manner. There was no evidence in the daily observations to indicate any adverse effect of treatments on germination and subsequent growth. The final examination showed no recognizable adverse effects of the insecticides on roots or stems.

In the second soil-treatment test, summarized in table 3, no kill was obtained with di (para-ethyl phenyl)dichloroethane and pentachlornitrobenzene. Kills with potassium ethyl xanthate ranged from 10 to 60 per cent and none of the plants were damaged by wireworms. Slight yellowing of the foliage in these treatments was ascribed to the action of the potassium ethyl xanthate.

The third and fourth soil-treatment tests, planted to oats, are summarized in table 4. These tests were conducted 2 weeks apart. Analysis of data for the two tests shows treatment differences for both criteria, that is, of kill of wireworms and of plant injury. Combining the data for both tests provided a more powerful statistic which clearly showed a grouping of the data into three sets as follows: (1) Most effective for protection against wireworms and kill of wireworms—heptachlor and lindane; (2) some protection and fair kill—aldrin, chlordane, and dieldrin; and (3) little protection and little kill—endrin, demeton and untreated check. These results are consistent for both tests as shown by the interaction χ^2 obtained by taking the difference between the total χ^2 and the same χ^2 for the individual tests as follows:

Interaction χ_7^2

$$\text{Kill} = 38.1 + 45.2 - 79.8 = 3.5,\ P = .83$$
$$\text{Injury} = 33.1 + 50.4 - 75.2 = 8.3,\ P = .35$$

No injury to seed or seedling was noted in any of the treatments at the daily and final examinations.

[6] The convention here is that the subscript on the χ^2 indicates the number of degrees of freedom associated with that particular value and is, in general, one less than the number of compounds compared.

In the third laboratory method of testing, 17 different insecticide-fertilizer mixtures were used, as summarized in table 5.

Large differences in plant injury and kill of wireworms occurred between materials. Furthermore, the same materials, when tried at different rates, did not show the same effects. For example, the low rate of heptachlor was not nearly as effective as the two higher rates, but aldrin appeared equally effective at all rates. Any average comparison of heptachlor and aldrin would have to take this fact into consideration because heptachlor at 2 or 4 pounds per acre gave a much greater kill than did aldrin at any rate, yet the average kill for all rates was 63 per cent for heptachlor and 56 per cent for aldrin —not a marked difference.

The highest percentage of kill, 84, was obtained with heptachlor at 2 pounds per acre. DDT, at 25 pounds per acre, produced no kill of wireworms after 8 days. A kill of 4 per cent was recorded in the untreated check and was ascribed to natural mortality.

Besides heptachlor and aldrin, two other compounds—parathion at 20 pounds per acre and lindane at 4 pounds per acre—produced a relatively high kill of wireworms. Relatively low kills were obtained with dieldrin at 4 pounds per acre, and with chlordane at 10 pounds per acre.

The higher dosages of most materials afforded fair protection against wireworm attack except dieldrin, chlordane and DDT which had 44 or more per cent of plants damaged by wireworms. In the untreated check, the percentage of wireworm damaged plants was 68.

DISCUSSION.—The best treatments, based on per cent of kill, of all control methods have been summarized in table 6. Average per cent kill by material was generally inversely proportional to the number of plants injured, that is, the greater the kill of wireworms, the fewer plants damaged. For example, heptachlor had an average kill for all methods of treatment of 76 per cent and only 4 per cent of plants were damaged whereas DDT had a kill of 3 per cent and 51 per cent of plants were damaged.

Based on average per cent kill by materials, heptachlor, aldrin, lindane, and dieldrin appeared to be the only effective materials. On the basis of plant damage, heptachlor scored the best with an average of 4 per cent and the next best material was lindane with an average of 18 per cent.

Average per cent kill based on method of treatment was 18 per cent with corn and 72 per cent with oats in treated soil. It should be remembered that with corn No. 10 tins were used with five wireworms and five seeds per can whereas with oats a 3-ounce pill box with one wireworm and one seed per box was used. These differences may account for the variation in average kills obtained rather than the insecticides used. Average per cent kill for the seed-treatment control method was equal to that for the insecticide-fertilizer method.

On the basis of the plant injury criterion, the lowest average percentage was recorded in the seed-treatment method with corn.

The performance of these materials in the different control methods used in the laboratory does not necessarily indicate their performance under field conditions. A previous report on seed coating (Kulash 1953) has stated the limitation of the seed coating method under field conditions.

SUMMARY.—Laboratory methods for control of wireworms, *Melanotus communis* (Gyll.), attacking corn were conducted with seed coatings, soil treatment, and insecticide-fertilizer mixtures. Thirteen different materials were used in several formulations. Most of the tests were conducted in gallon-size tin cans with 5 wireworms, 5 seeds, and 5 replicates. Efficacy of methods and materials was based on percentage of wireworms killed and plants damaged by wireworms.

The greatest kills were obtained with heptachlor, aldrin, lindane, and dieldrin. Heptachlor gave the best protection against wireworm damage. The largest dosage of insecticide did not necessarily produce the greatest kill of wireworms as was noted in seed-coating with aldrin and dieldrin and in the insecticide-fertilizer treatment with heptachlor. The insecticide-fertilizer and seed-coating methods resulted in fair kill and a good amount of protection against wireworm damage.

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Insecticide Tests for Tobacco Flea Beetle Control

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The tobacco flea beetle, *Epitrix hirtipennis* (Melsh.), is an important insect pest affecting the production of flue-cured tobaccos. In Virginia during the 1953 transplanting season heavy flea beetle infestations resulted in severe foliage injury and root damage. This condition no doubt was a contributing factor to many incomplete stands and to tobacco plants which failed to make proper growth for several weeks after transplanting.

This paper is a report on tests conducted with organic insecticides at the Tobacco Research Station, Chatham, Virginia, for the control of the tobacco flea beetle in plantbeds, on newly set plants, and on field tobacco. With the exception of the tests with insecticide dusts on field tobacco, all experiments were conducted during the 1953 season.

Tobacco Plantbeds.—In the plantbed tests, a complete randomized-block design was used, the tobacco plantbeds being arranged singly at two locations. Each plot was 3 yards in length and 2 yards wide and was replicated twice at each location.

The sprays were applied at the rate of 3 gallons for the first and 6 gallons for the second application per 100 square yards of plantbed area with single nozzle sprayers. The dusts were applied at the rate of 0.5 pound for the first and 1 pound for the second application with hand dusters. Treatments were made on April 17 (plants 2 to 4 leaf stage) and again on May 7 immediately after removing the plantbed covers for hardening the plants.

The final results were determined on May 13, 6 days following the second application, by drawing 100 plants at random from each plot and examining for evidence of flea beetle punctures. Plants showing one or more punctures resulting from flea beetle feeding were scored as injured. The flea beetle population in each plot was sampled by sweeping the plants with a net. No rain fell and no artificial irrigation was applied between the date of the last application and the date the counts were made.

Table 1.—Control of the tobacco flea beetle in plantbeds with organic insecticides.

Insecticide	Per Cent Uninjured Plants	Flea Beetles Five Net Sweeps
Sprays[1]		
DDT, 75% w.p.	49	13
Endrin, 18.5% e.c.	46	11
Dieldrin, 25% w.p.	44	8
Dusts:		
CS-708, 5%	56	13
DDT, 5%	48	10
Isodrin, 2%	44	13
Dieldrin, 1%	43	10
Check	0	56

[1] Rates per 100 gallons used were: DDT, 1.5 pounds; endrin, 1 quart; and dieldrin, 1.5 pounds.

The insecticides used and the results obtained are summarized in table 1. There was little evident difference in the performance of the various treatments; however, the check plots showed moderate to severe injury. Two of the check plots showed a reduction in plant stand of approximately 50 per cent. Among the spray treatments, the results with DDT showed a slightly higher percentage of uninjured plants. Among the dust treatments, 5 per cent CS-708 gave the highest percentage of uninjured plants. There was little difference in the flea beetle population sampled from the various treatments.

Newly Set Tobacco.—A pretreatment in the tobacco plantbed with DDT dust, or a spray containing DDT has been recommended and generally used by tobacco growers in the control of the tobacco flea beetle on newly set plants for several years. The purpose of the following experiment was to compare DDT with other organic insecticides, the materials being applied as a pretreatment. The sprays were applied at the rate of 6 gallons and the dusts at 1.5 pounds per 100 square yards of plantbed area. Tobacco plants treated in this manner were set in 1/56-acre plots and each treatment was replicated four times in a randomized-block design. The results were determined by making a count of the live flea beetles on 10 plants selected at random from the two center rows of each plot, 5, 10 and 14 days following transplanting to the field. The most injured leaf on each of 10 plants

Table 2.—**Pretreatment tests with organic insecticides for the control of the tobacco flea beetle on newly set tobacco.**

	Days After Transplanting						
	5		10		14		15
Treatment	Av. No. Beetles per Plant	Per Cent Reduction	Ave. No. Beetles per Plant	Per Cent Reduction	Ave. No. Beetles per Plant	Per Cent Reduction	Ave. No. Leaf Punctures
Sprays:[1]							
Dieldrin, 25% w.p.	1.0	84.4	0.7	93	0.6	92.5	30
DDT, 75% w.p.	0.8	87.5	3.6	64	1.0	87.5	54
Dusts:							
DDT, 5%	0.6	90.6	1.6	84	0.4	95.0	34
Isodrin, 2%	0.7	89.1	2.0	80	0.9	88.8	28
Dieldrin, 1%	0.7	89.1	3.3	67	0.9	88.8	33
CS-708, 5%	1.1	82.8	3.7	63	1.2	85.0	40
Check	6.4	—	10.0	—	8.0	—	186

[1] Rates per 100 gallons used were: dieldrin, 1.5 pounds; and DDT, 1.5 pounds.

from each plot was selected and the average number of feeding punctures computed.

The materials used and the results obtained are presented in table 2. These data indicate that dieldrin was superior to DDT over the 14-day period. Leaf puncture counts on the most injured leaf showed an average of 30 for dieldrin compared to 54 for DDT. The flea beetle count 10 days after transplanting indicates a build-up on the DDT-treated plants, while a slight reduction was revealed on the dieldrin-treated plants. Among the dusts, DDT gave a slightly higher reduction in flea beetles over the 14-day period, whereas, except for CS-708, little difference was revealed in the leaf-puncture counts. In the tests, 5 per cent CS-708 was the least effective; however, all treatments were highly effective when compared with the checks.

Tests with Systemics.—Ashdown & Cordner (1952) reported that eggplants grown in soil into which demeton had been incorporated prior to transplanting were protected from both flea beetles and lace bugs. In the following experiment, preliminary tests were conducted with two systemic insecticides, demeton and G-23611,[1] used in the tobacco transplant water at different dilutions. The diluted insecticides were used in place of the transplant water commonly used for tobacco. A measured 65 ml. per plant was used and the check plants received the same amount of water. The plants were set in one-row randomized plots, 55 plants per

[1] 1-isopropyl-3 methyl-pyrazolyl-(5)-dimethylcarbamate.

Table 3.—**Control of the tobacco flea beetle on newly set tobacco with systemic insecticides applied as transplant water.**

		Days After Transplanting						
		5		10		14		15
Treatment	Dilution	Ave. No. Beetles per Plant	Per Cent Reduction	Ave. No. Beetles per Plant	Per Cent Reduction	Ave. No. Beetles per Plant	Per Cent Reduction	Ave. No. Leaf Punctures
Demeton[1]	1–1600	1.8	70.0	0.4	96	0.6	92.5	30
	1–2400	3.4	43.3	0.5	95	0.8	90.0	45
	1–3200	2.8	53.3	0.9	91	1.4	82.5	46
	1–6400	3.2	46.7	0.7	93	1.5	81.3	61
	1–12800	4.2	30.0	0.9	91	2.3	71.3	72
G-23611[2]	1–1600	0.6	90.0	0.3	97	0.5	93.8	46
	1–3200	1.7	71.6	0.3	97	0.7	91.3	38
Check	—	6.0	—	10.0	—	8.0	—	150

[1] 4 pounds per gallon.
[2] 25 per cent.

Table 4.—Tests with insecticide dusts for the control of the tobacco flea beetle on field tobacco.

Insecticide	Pounds Active Ingredient per Acre	Pretreatment Beetle Count Ave. per Plant	Per Cent Reduction		
			Days After Treatment		
			1	4	8
DDT, 5%	1	27	99.2	93.3	89.3
CS-708, 5%	1	21	99.5	89.5	84.3
Isodrin, 2%	0.4	23	99.1	85.6	88.7
TDE, 10%	2	20	97.0	79.5	72.0

row, and two replications were used. Flea beetle and leaf-puncture counts were made following transplanting as indicated in table 3.

The dilutions used and the results obtained are presented in table 3. These data indicate that both materials at all dilutions caused a substantial reduction in the flea beetle population when compared with the check plots. There was also a substantial reduction in the amount of leaf injury. The greatest per cent reduction in flea beetles per plant for all dilutions occurred in the count made 10 days following transplanting. This differed from the foliage-applied insecticides in that the greatest reduction occurred on the first count, 5 days following transplanting. In a count made 30 days after transplanting the plots showed flea beetle populations similar to that of the checks, approximately 10 beetles per plant. Demeton at the first three dilutions caused stunting when compared with the latter two dilutions; however, their rate of growth was equal to, or better than the checks. Demeton at the dilutions of 1–6400 and 1–12,800 showed no phytotoxic symptoms and the treated plants were well advanced in growth over the checks. G-23611 gave a highly substantial reduction in the flea beetle population and showed fewer beetles on the initial count than demeton. No phytotoxic symptoms were noted when this material was used and the plants were further advanced in growth than the checks.

CONTROL OF FIELD TOBACCO.—The tobacco flea beetle is frequently a major problem on field tobacco. Flea beetle and hornworm infestations often coincide; thus emphasis has been placed recently on the finding of a satisfactory insecticide that would effectively control both insects with the same application. During the late growing season of 1952, an experiment was conducted with several insecticides used in the dust form. The plots were 1/40-acre in size, randomized and replicated three times. The dusts were applied with rotary hand dusters at approximately 20 pounds per acre. The results were determined by making a pretreatment count of the flea beetles on 10 random plants from the two center rows of each plot and at intervals as indicated in table 4.

The materials used and the results obtained are presented in table 4. These data indicate that a highly effective initial reduction occurred for all treatments. However, a gradual build-up was revealed in counts made on the fourth and eighth day following treatment. DDT and isodrin gave the longer residual control. The greatest build-up of flea beetles occurred in plots treated with TDE, 10 per cent.

Allen *et al.* (1953) reported that an endrin emulsion as a high-volume spray killed a high percentage of tobacco hornworm larvae and was quicker in lethal action than TDE, the insecticide currently recommended for hornworm control on tobacco. In the following experiment, endrin and TDE were tested as low-volume sprays for the control of the tobacco flea beetle. The plot size and the procedure were essentially the same as described for the first experiment. The sprayer was equipped with *Tee-jet* nozzles and the output was approximately 11 gallons per acre.

The results are summarized in table 5. In the tests, endrin at comparatively lower dosages gave a much quicker reduction and was more effective than TDE. Only a slight build-up was revealed in the counts made 8 days after the treatment. TDE was much slower in action and

Table 5.—Tests with endrin and TDE emulsifiable concentrates for the control of the tobacco flea beetle on field tobacco.

Insecticide	Pounds Active Ingredient per Acre	Pretreatment Beetle Count Ave. per Plant	Per Cent Reduction			
			Days After Treatment			
			1	3	5	8
Endrin	0.1	41	97.6	97.0	95.6	93.4
	0.2	44	99.5	99.8	99.3	97.7
	0.4	28	99.8	100.0	99.3	97.1
TDE	0.5	37	27.0	40.5	64.8	64.8
	1.0	31	32.3	58.1	70.9	64.4
	1.5	27	59.3	78.5	81.5	70.4

failed to give effective control even at the dosage of 1.5 pounds per acre.

SUMMARY.—The tobacco flea beetle, *Epitrix hirtipennis* (Melsh.), is an important pest of flue-cured tobaccos. Since it is a problem on all stages in the growth of the plant, the insect is often responsible for heavy losses.

Experiments with insecticides for the control of the tobacco flea beetle were conducted in plantbeds, on newly set tobacco, and field tobacco. In plantbeds, DDT, dieldrin, isodrin, endrin and CS-708 all gave satisfactory control. On newly set tobacco, dieldrin as a spray and DDT 5 per cent dust gave the longer residual control. Preliminary tests with two systemic insecticides used in the tobacco transplant water showed potential possibilities. On field tobacco 5 per cent DDT and 2 per cent isodrin dusts gave the longer residual protection for the dust treatments. In low-volume spray tests, endrin at low dosages gave a rapid reduction in the flea beetle population and was more effective than TDE.

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Japanese Beetle Damage to Corn as Influenced by Silking Date

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Although the larvae of the Japanese beetle may cause damage to the roots of corn and the adults feed to some extent on the leaves and tassels, by far the most serious damage to corn by this insect is that which results from the feeding of the adults on the silks and ear tips. The silk cutting may be severe enough to prevent completely the pollination of many ears and to interfere more or less seriously with the pollination of most of the others, especially near the edges of the fields. Langford *et al.* (1944) reported reductions of 40 per cent in corn yields in Maryland as a result of the silk cutting done by the Japanese beetle. In recent years in the heavily infested area of northern Virginia fields have been observed in which losses from this cause were 30 per cent or greater. In addition to the loss caused by poor pollination, the feeding of the beetles on the ear tips may expose the grain to infection by rot organisms and to damage by birds.

A study of the damage to corn caused by the silk cutting of the Japanese beetle was started in Virginia in 1951. During the seasons of 1951, 1952, and 1953 observations of damage were made in corn fields. In 1952 and 1953 experimental plantings of corn were made at different dates in order to get more detailed information on the damage from silk cutting in relation to the silking dates.

METHODS.—In 1951 the date of planting and the hybrid grown in each field examined were ascertained because of the possible bearing of these factors on the amount of damage from silk cutting. Dates of silking were not recorded. In 1952 and 1953 semi-weekly observations were made in each field during the period of high Japanese beetle infestation to determine the time that the corn reached the stage of full silk. Notes were also made on the amount of feeding being done by beetles at each visit.

After the corn was completely pollinated, or the possibility of further pollination was past, examinations were made in each field to determine the degree of damage from silk cutting. Ears were examined on the outside row of each field and at 5-row intervals from the border toward the center of the field to determine

Table 1.—Japanese beetle damage to corn at various distances from the edges of the fields, Northern Virginia, 1951–53.

Row from Edge of Field		Per Cent Damage to Ears by Silk Cutting		
		1951	1952	1953
1st	Average	7.1	2.5	3.3
	Maximum	30	25	60
6th	Average	3.9	1.18	1.7
	Maximum	21	13	32
11th	Average	2.5	0.6	0.8
	Maximum	16	9	14
16th	Average	—	0.3	0.5
	Maximum	—	6	10
21st	Average	1.6	0.2	0.2
	Maximum	11	4	5
26th	Average	—	0.1	<0.1
	Maximum	—	5	2
31st	Average	—	0.1	<0.1
	Maximum	—	4	1
41st	Average	0.7	—	—
	Maximum	5	—	—
General Average	Average	2.9	0.7	0.7
	Maximum	16.6	8.4	24.2

the amount of damage at each place.

The experimental plantings made in 1952 and 1953 consisted of six hybrids planted at three different dates. Each plot contained four rows of 10 hills each. The plantings were replicated six times. The entire experimental planting was placed along the border of the field so that the exposure of the plots to attack by the Japanese beetle might be even.

Results.—Drought injury was so severe in the experimental plantings in 1952 and 1953 that no detailed information was obtained from these experiments. Drought injury may result in many unfilled or partly filled ears similar to the damage caused by silk cutting. It is difficult or impossible, under these conditions, to distinguish satisfactorily the ears damaged by drought from those damaged by silk cutting. The drought injury was so severe that much of the corn on the experimental plots produced only nubbins. It was noted in 1952, however, that the corn which reached the full-silk stage during the last 10 days of July was more severely damaged by silk cutting than that which reached this stage after the first of August. In 1953 the corn which silked before July 23 was less severely damaged than that which reached this stage during the last week in July. The corn which silked after August 1 in 1953 was very severely damaged by drought, and the damage from silk cutting could not be estimated.

Three seasons of field examinations confirmed the common observation that damage from silk cutting by the Japanese beetle is usually much heavier along the edges of the fields than in the interiors, table 1. This damage was found to decrease at the rate of 33 to 50 per cent for each 5 rows' distance from the edge of the field. In most fields this equals 16.5 to 18.5 feet. When the infestation and damage are generally light, as was the case in 1952 and 1953, these areas of relatively greater damage provide a better basis for comparison among fields than the lighter average damage.

Exceptions to this rule were occasionally found, usually where a large quantity of a favorite weed host of the Japanese beetle had been allowed to grow in a corn field. Under these conditions the beetles had been attracted into the fields in large numbers by the weeds, and were thus present to attack the silks all over the field as soon as they appeared, instead of spreading slowly from the edges inward, as is usual. Coon (1946) has shown that only a few hours is required for pollination to be completed after pollen falls on the silks. Thus a few days' delay in attack by the beetles may be of great importance. When the attack progresses slowly from the

Table 2.—Japanese beetle damage to corn planted at different dates, Northern Virginia, 1951.

Planting Dates	Number of Fields		Per Cent Damage to Ears by Silk Cutting on Designated Row from Edge of Field		
			1st	40th	Average
May 3	9	Average	1.4	0.1	0.5
		Maximum	7	2.5	1.8
May 7–10	9	Average	5.3	0.1	2.0
		Maximum	18	1	6.5
May 12–15	12	Average	11.1	1.7	5.1
		Maximum	21	5	15
May 18	6	Average	9.7	0.3	4.6
		Maximum	25	1	13
May 23–26	9	Average	10.2	0.9	4.8
		Maximum	30	5	16
June 3–10	4	Maximum	0	0	0

edges of the field many ears will be pollinated before they are attacked.

In 1951 in a Fauquier County corn field a loss of 50 to 60 per cent in yield as a result of silk cutting was observed. There was a heavy growth of smartweed in the field, and these weeds were heavily infested by Japanese beetles before the silks appeared. Damage was more severe at some points within the field than along the edges, which is unusual. In each instance where severe damage from silk cutting has been observed at a considerable distance from the edge of a field, weed hosts of the Japanese beetle were common within the field.

The results of the 1951 observations are shown in table 2. The silking dates were not obtained for many of these fields, but most of those planted May 3 had reached the full-silk stage before July 20. About half of the fields planted July 7 to 10 had also silked before July 20. Many of the fields planted May 12 to 18 reached full silk during the last week of July. The infestation of beetles was at its height during this period, and severe damage from silk cutting resulted. The fields planted in June did not come into silk until after August 1, and they escaped damage because the beetle population had dropped greatly by that time.

The results of the 1952 observations are shown in table 3, and those of 1953 in table 4. The infestation of Japanese beetles was generally lower both seasons than in 1951. Most corn fields were injured only moderately, if at all. Several fields which reached the full-silk stage during the last week of July, however, were severely damaged, while the corn which silked earlier or later generally escaped severe damage.

Table 3.—Japanese beetle damage to corn silking at different dates, Northern Virginia, 1952.

Date of Silking	Number of Fields		Per Cent Damage to Ears by Silk Cutting on Designated Row from Edge of Field		
			1st	30th	Average
Before July 23	16	Average	1.1	0	0.3
		Maximum	3	0	1
July 24–28	18	Average	6.7	0.2	1.9
		Maximum	25	4	8.4
July 29–Aug. 1	8	Average	4.7	0	1.3
		Maximum	15	0	5
Aug. 2–4	7	Average	1.9	0	0.4
		Maximum	5	0	1
After Aug. 4	18	Average	0.06	0	0.008
		Maximum	1	0	0.01

Table 4.—Japanese beetle damage to corn silking at different dates, Northern Virginia, 1953.

Date of Silking	Number of Fields		Per Cent Damage to Ears by Silk Cutting on Designated Row from Edge of Field		
			1st	30th	Average
Before July 14	10	Maximum	0	0	0
July 15–20	17	Average	0.3	0	0.05
		Maximum	4	0	0.7
July 21–24	19	Average	7.4	0	2.0
		Maximum	30	0	11.2
July 25–28	8	Average	17.1	0	4.9
		Maximum	60	0	24.2
July 29–Aug. 1	5	Average	2.8	0	0.6
		Maximum	6	0	1.3
Aug. 2–12	7	Maximum	0	0	0

DISCUSSION.—The information obtained in 3 years of observations on damage from silk cutting by the Japanese beetle indicates that most of the damage can be avoided if corn reaches the silking stage before the period of high beetle infestation, or after most of the beetles have disappeared. During these seasons no severe injury was observed in corn fields which reached the silking stage before July 20 or after August 1.

The presence of preferred hosts of the Japanese beetle in edges of woods or fence rows adjacent to corn fields may result in more severe damage to the corn if it is silking when the beetles are abundant. The presence of such hosts will not result in severe injury, however, if the corn is already pollinated when the high infestation occurs, or if it does not silk until after most of the beetles have disappeared. The presence within a field of a heavy stand of a favorite weed host of the Japanese beetle may result in more severe damage, and may also result in the extension of the area of severe damage farther into the field, instead of its being confined to the borders, which is the usual condition.

During the years since the Japanese beetle became common in northern Virginia, the peak of abundance of adults has always occurred between July 23 and July 27, except in 1950, when it was about two weeks later. The period of maximum infestation has been constant enough to justify the recommendation that corn be

planted at such dates that it will not reach the silking stage during the last 10 days of July.

Recommendations are not made for actual planting dates, but agronomists should be able to suggest such dates for many of the hybrids commonly grown. Earlier planting, rather than later, is generally preferable, because of the need to have corn mature and harvested early enough to permit the seeding of a small grain afterward. The trend toward harvesting by corn picker will also influence the farmers toward planting as early as practicable, because this method of harvesting requires that the corn mature early.

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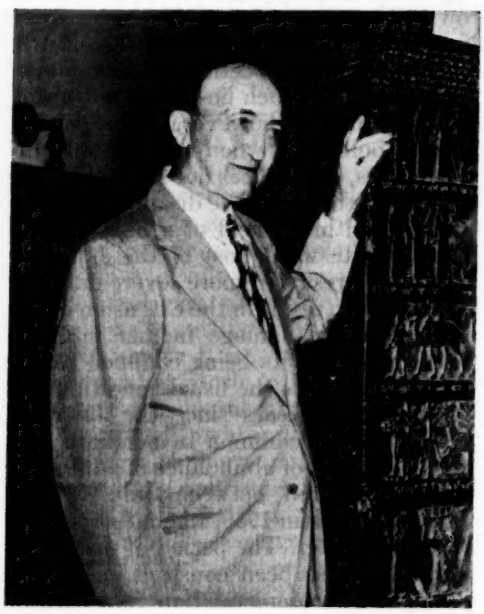
OBITUARY

Perry Wilbur Fattig
1881-1953

Mr. Perry Wilbur Fattig died suddenly in his home in Decatur, Georgia, on December 7, 1953. Thus ends the career, at the age of 72, of an eager naturalist, tireless collector, and a modest and thoroughly friendly person.

P. W. Fattig was born in Lancaster, Ohio, on June 1, 1881. He studied at Crawfis Collegiate Institute, Ohio University, Ohio State University. He took degrees of B.S. and M.S. from Ohio University and a B.S. in Education from Ohio State Normal College.

On September 2, 1903, he was married to Miss Clara Mae Fenstermaker. Mrs. Fattig, a son, Wilbur L. Fattig of Atlanta, and a brother, D. E. Fattig of Youngstown, Ohio, survive him.



Mr. Fattig taught at Trinity University in Texas, State Teachers College in North Dakota, the University of Florida, and State Teachers College in Virginia. Since 1926, he held the position of Curator of the Museum at Emory University near Atlanta, Georgia, in which position he did much to stimulate the interest of high school and college students in entomology and natural history generally.

He contributed many notes on the biology of the insects he collected and completed ten Emory University Museum Bulletins, giving biological notes and listing the Georgia collection records on the following groups: Mutillidae (1943), Phyllophaga, Asilidae, Tabanidae, Cerambycidae, Chrysomelidae, Carabidae, Larvaevoridae, Ichneumonidae, and Elateridae (1951). He had almost completed the "Buprestidae of Georgia" at the time of his death. These bulletins demonstrate both the wealth of the Georgia insect fauna and the energy and persistence of Mr. Fattig's collecting, since in all groups the number of species listed far outnumbers that found in lists from nearby States.

Mr. Fattig was a charter member of the Georgia Entomological Society and served as its president in 1943 and 1944. He attended every meeting of the Society since its founding in 1937, except the 1951 meeting in Savannah. He was Historian at the time of his death. He was a long-time member of the American Association of Economic Entomologists and of several fraternal organizations.

Mr. Fattig's warm personality, his phenomenal memory, his energetic devotion to the exploration and study of the insect fauna of Georgia, and his many fascinating exploits in collecting insects have made him an almost legendary figure that will be remembered gratefully as long as insects are studied in Georgia.

HORACE O. LUND

SCIENTIFIC NOTES

A Dust Mixer for Economic Poisons[1]

YUNG-CHANG CHAO, *Department of Entomology*, and J. ROBERTS, *Department of Agricultural Engineering, State College of Washington, Pullman*

The mixer herein described was constructed primarily to blend wheat samples thoroughly with various insecticidal protectants. It is a modification of two similar mixers. One was developed by Dr. Samuel Ristich, and described and illustrated in the senior author's doctoral thesis (1952);[2] the other was devised and illustrated by McCallan (1948).

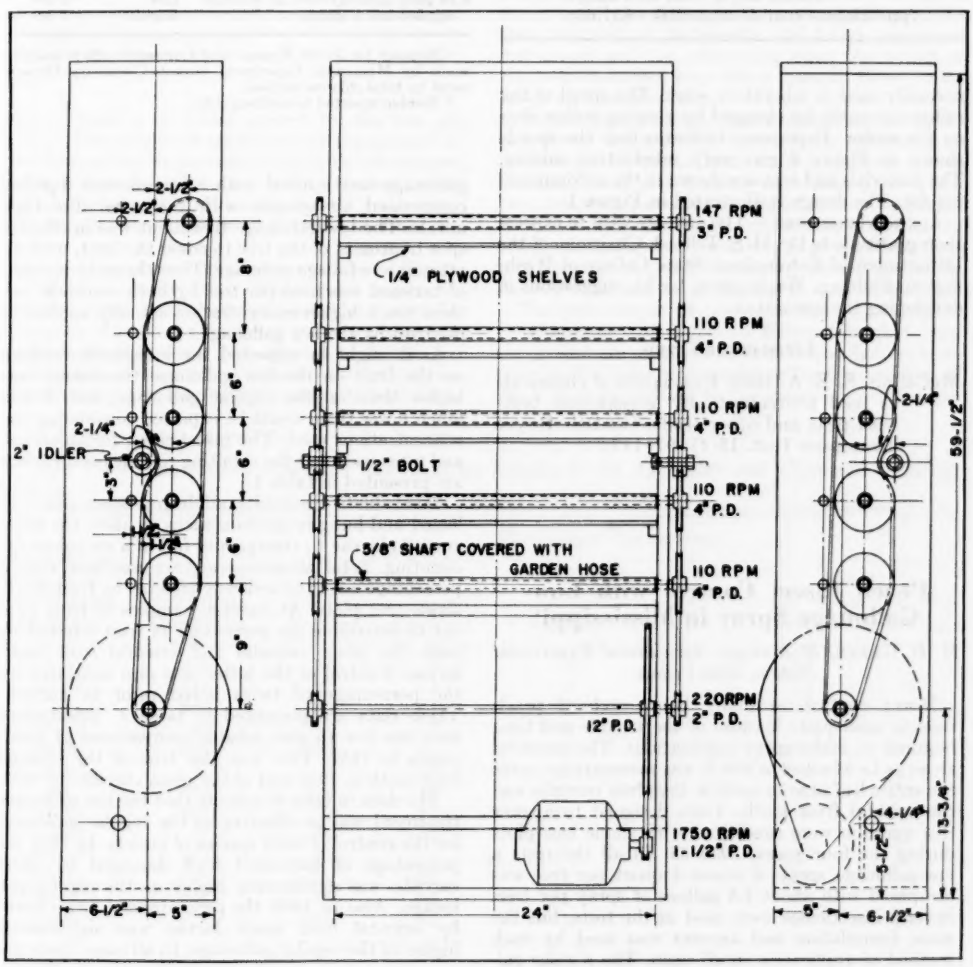
It was our desire to develop equipment which would:

(1) Blend rapidly and thoroughly a large number of samples varying from less than an ounce up to 5 pounds.
(2) Be simple to construct and inexpensive.
(3) Be fairly portable and consume little floor space.

This machine meets all of these requirements adequately and should also be useful in many other types of laboratory studies. The distance between the rollers can be adapted to containers of any size

[1] Work conducted under Project No. 1127, State College of Washington, Pullman.

[2] Chao, Yung-Chang, 1952. Comparative effectiveness against the granary weevil of contact, fumigation, and repellency of Pyrenone, pyrethrins, piperonyl butoxide, lindane, and DDT. Ph.D. thesis, Ohio State University.



Scale 1/4" = 1'

FIG. 1.—A design of the dust mixer.

List of Materials for the Mixer, Pullman, Washington. 1953.

QUANTITY	MATERIAL
1	Motor, ¼ h.p., 1750 RPM
8	V pulley, A Section, die cast, 4½″ P.D., ⅝″ bore
1	V pulley, A Section, die cast 12.4′ P.D., ⅝″ bore
2	V pulley, A Section, steel 2.3″ P.D., ⅝″ bore
2	V pulley, A Section, Steel 3.4″ P.D., ⅝″ bore
2	V belt, 78″, A Section
1	V belt, 44″ A Section
30 feet	Cold rolled steel, ⅝″
3 pounds	Flat washers, ⅝″
10 feet	Extension cord, 2–16, with plug
1 piece	Oak, 1″×12″×10′
1 piece	Ply wook, 8′×4′×¼″
1	Rubber garden hose, 25′, ⅝″ I.D.
2	Idler pulleys, 3″
	Bolts, keys, nails and hinges
Approximate cost of materials—$57.65.	

normally used in laboratory work. The speed of the rollers can easily be changed by varying pulley sizes on the motor. Experience indicates that the speeds shown in Figure 2 give very satisfactory mixing. The materials and cost are shown in the accompanying list. The design is illustrated in Figure 1.

ACKNOWLEDGMENT.—The authors wish to express their gratitude to Dr. H. S. Telford, Chairman of the Department of Entomology, State College of Washington, Pullman, Washington, for his suggestions in developing the apparatus.

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Peach Insect Control with Low-Gallonage Spray in Mississippi[1]

H. B. GREEN, *Mississippi Agricultural Experiment Station, State College*

Insect control on many home orchard peach trees is inadequate because of the trouble and time required to make spray applications. The question arose as to whether or not it was necessary to cover the entire leaf area to control the plum curculio and the oriental fruit moth. Tests designed to answer this question were conducted with single tree plots during the four years, 1950–53. In all the tests a low-gallonage spray of about 1 quart per tree was compared with about 1.5 gallons of spray per tree. Several insecticides were used in the tests, but the same formulation and amount was used by each method of application in all cases. The regular gallonage was applied with a 15-gallon power sprayer developing 150 pounds p.s.i. pressure, while the low gallonage was applied with a commercial 3-gallon compressed air sprayer with the usual disc type nozzle. The low-gallonage treatment was in effect a spot treatment of the tree to cover the fruit, with no attention to foliage coverage. Thus the same amount of toxicant was used per tree by both methods, but there was a higher concentration actually applied to the fruit by the low gallonage.

Table 1.—Summary of sprays used and residues reported.

INSECTICIDE PER TREE (GMS. OF ACTUAL TOXICANT)	METHOD OF APPLICATION	RESIDUE P.P.M.
1950		
5.17 gms. chlordane as emulsion plus 6.88 gms. DDT as emulsion	Low Regular	No analysis
1951		
3.58 gms. aldrin as wettable powder plus 6.88 gms. DDT as wettable powder	Low Regular	0.12[1] 0.20[1]
1952		
53.51 gms. toxaphene as emulsion	Low Regular	76.12 31.77
6.88 gms. methoxychlor as emulsion	Low Regular	7.24 4.42
3.44 gms. dieldrin as wettable powder	Low Regular	0.57 None
1953		
3.44 gms. dieldrin as wettable powder applied first two sprays		
6.88 gms. methoxychlor as wettable applied last 4 sprays	Low Regular	6.44[2] 4.18[2]

[1] Bioassay by Julius Hyman and Company; other analyses made by Mississippi Experiment Station Chemistry Department by total chlorine method.
[2] Residue reported as methoxychlor.

As it might be expected the insecticide residues on the fruit on the low gallonage treatments was higher than on the regular gallonage, but it was much lower than would be expected considering the concentrations used. The insecticides, formulations, and rates used and the resulting residue on the fruits are presented in table 1.

To evaluate the results, all drop peaches were collected and hung in produce sacks to allow the plum curculio larvae to emerge and fall in a container for counting. Total larvae emerged are used here, since a percentage might be seriously affected by fruit set on single tree plots. At harvest, samples of fruit were cut to determine the percentage of fruit infested by both the plum curculio and oriental fruit moth larvae. Control of the latter was also measured by the percentage of twigs bored prior to harvest. These data are presented in table 2. Infestations were too low to give reliable comparisons of treatments in 1952. This was also true of the oriental fruit moth in 1951 and of the plum curculio in 1953.

The data in table 2 indicate that the low gallonage treatment was as effective as the regular gallonage for the control of both species of insects. In 1951 the percentage of harvested fruit damaged by plum curculio was significantly higher on the regular gallonage. Also in 1953 the percentage of twigs bored by oriental fruit moth larvae was significantly higher in the regular gallonage. In all cases there was

[1] Journal Article No. 364, Miss. Agri. Exp. Station.

Table 2.—Summary of insecticide effectiveness.

Gallonage	Plum Curculio Larvae Collected From all Drops	Wormy Friut (Plum Curculio) at Harvest	Twigs Bored by Oriental Fruit Moth Larvae
	Number	*Per Cent*	*Per Cent*
Average of 2 Paired Replicate of Belle of Georgia Variety at State College, Miss.			
	1950		
Low	12.50	1.55	4.33
Regular	13.33	1.58	8.25
	1951		
Low	21.91	5.58	
Regular	38.91	10.25*	
	1953		
	(Oriental Fruit Moth)		
Average of 8 Paired Replicates of Belle of Georgia & Elberta Varieties at Stoneville, Miss.			
Low		5.12	16.25
Regular		9.87	25.87†

* Significant at 5 per cent level.
† Significant at 1 per cent level.

some indication of better control by the low gallonage. This might be explained by the greater insecticide residue in the case of the fruit infestations, but it is more difficult to account for the better control of the oriental fruit moth larvae in the twig tips, which were usually well removed from the fruit.

Several fungicides were used in a comparable manner throughout the tests. When some insecticide emulsions were used the large amounts of wettable fungicides often had a tendency to form a sludge in the low-gallonage tests. Nabam was used with fair success, but it is more or less a solid suspension when the necessary zinc or ferric sulphate is added to it. Under most conditions wettable sulphur was satisfactory with occasional shaking of the compressed air sprayer to agitate it.

Applications required about the same amount of time by either method which was much faster than regular gallonage could be applied with a compressed air sprayer. The low-gallonage method is also much easier to use since the high shoots and twigs are not covered and application may usually be made from the tree crotch or the ground.

Parasitization of Spruce Budworm Larvae at Different Crown Heights by *Apanteles* and *Glypta*

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Studies to determine the distribution of overwintering larvae of the spruce budworm, *Choristoneura fumiferana* (Clem.), on balsam fir were made during a medium infestation in northern Maine late in April of 1951 and 1952. Branches were cut from 16 trees, usually at 5-foot height intervals. Some trees were sampled at mid-crown and lower, others at mid-crown and top, depending upon the height of the tree. Branches were taken from all three crown levels on 11 of the trees.

Limited records regarding parsitization at different crown heights had shown little difference in percentage of parasitization by *Apanteles fumiferanae* (Vier.) and *Glypta fumiferanae* (Vier.), the two principal parasites of overwintering budworm larvae. It was believed that dissection of the larvae obtained during this work would give an excellent indication of the distribution of parasitization by these species, and so all the larvae were dissected.

The percentages of budworm larvae parasitized by *Apanteles* and *Glypta* at different heights from the ground are shown in table 1. These figures, however, do not take into consideration the position of the branch in relation to the crown of the tree. On

Table 1.—Parasitization of spruce budworm on balsam fir by *Apanteles* and *Glypta* at different heights.

Height of Branch (Feet from Ground)	Number of Budworms Dissected	Budworms Parasitized					
		Apanteles		*Glypta*		Total	
		Number	Per Cent	Number	Per Cent	Number	Per Cent
7–10	270	25	9	13	5	38	14
10–15	148	22	15	3	2	25	17
15	322	35	11	21	6	56	17
15–20	58	4	7	2	3	6	10
20–22	608	128	21	55	9	183	30
15–28	53	8	15	3	6	11	21
25	570	116	20	69	12	185	32
25–32	226	57	25	22	10	79	35
20–33	57	26	46	3	5	29	51
30–32	433	83	19	37	9	120	28
30–35	116	37	32	12	10	49	42
35–37	129	46	36	14	11	60	47
42–47	112	38	34	11	10	49	44
Total or average	3102	625	20	265	9	890	29

Table 2.—Parasitization of spruce budworm on balsam fir by *Apanteles* and *Glypta* at three crown heights.

Portion of Tree Crown	Number of Budworms Dissected	Budworms Parasitized					
		Apanteles		*Glypta*		Total	
		Number	Per Cent	Number	Per Cent	Number	Per Cent
Low	1192	167	14	72	6	239	20
Middle	1472	305	21	154	10	460	31
High	438	152	35	39	9	191	44
Total or average	3102	625	20	265	9	890	29

some trees a limb at 15 or 20 feet would be considered part of the mid-crown, whereas on other trees it would be in the lower crown section.

When the samples are grouped into three crown levels—low, middle, and high—the difference in parasitization is evident (table 2). The difference is more pronounced for *Apanteles* than for *Glypta*.

The results from the 11 trees having branches sampled in the three crown classifications were analyzed for parasitization by *Apanteles*. The mean percentages of parasitization were 15, 20 and 27 for the low, middle, and high levels, respectively. The difference between means is significant at the 5-per cent level. The difference in parasitization at different crown levels would have been even more evident if the branch samples had been taken at 10- or 15-foot intervals rather than every 5 feet. The difference between trees was not significant, although the sample spruce budworm count ranged from 65 to 462, with an average of 245.

The results of this study show that the percentage of parasitization by *Apanteles* in a medium infestation on balsam fir varies at different crown levels, being greater at the higher levels. In order to get the most reliable estimate for parasitization by this species, collections should be made throughout the whole crown. This is often a practical impossibility because the tops of the larger trees are too high to be reached with the 30-foot sectional pole pruner used for this work. Fortunately, though, data presented in table 2 show that the parasitization at the mid-crown is a reliable indication of the average of parasitization for the whole tree.

Typhlodromid Mites on Citrus and Avocado Trees in Southern California

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The following note is a partial result of a close study of the predatory mites found on both citrus and avocado trees in southern California. A more detailed and comprehensive report on them will be forthcoming in a later publication.

Originally most of the Typhlodromid mites found on foliage were placed in a complex of species loosely called *Seius* (*Seiulus*) *pomi* (Parrott) (Nesbitt 1945). With subsequent collecting and more detailed studies we now recognize from citrus and avocados at least six described species and possibly two undescribed forms belonging to the genus *Typhlodromus* as it is now known.

Two of the most common Typhlodromid mites encountered in our studies are *Typhlodromus finlandicus* (Oudemans) and an undescribed species near *finlandicus*. Both mites have been observed, in the laboratory, to feed on plant-feeding mites of the family Tetranychidae. In the field these predatory mites have proved to be the most effective predators of Tetranychid mites occurring on citrus and avocado trees.

The following is a list of the Typhlodromid mites that we have encountered on both citrus and avocado trees; together with what information is available about their food ranges at this time. It might be added that the results were arrived at in the laboratory by confining the predators and plant-feeding mites in small cells, attached either to avocado leaves or orange fruit.

Typhlodromus finlandicus (Oudemans) occurs on both citrus and avocado trees. It has been observed to feed upon the citrus red mite, *Metatetranychus citri* (McG.), the citrus bud mite, *Aceria sheldoni* (Ewing), and the avocado brown mite, *Paratetranychus coiti* McG.

Typhlodromus conspicuus (Garman) has been found on citrus and avocado trees. It is more commonly found on those avocado trees where the pallid mite, *Tydeus californicus* (Banks), abounds. This predatory mite has proved to be unique in that it is the only Typhlodromid tested that will feed or reproduce on *T. californicus*. *T. conspicuus* when placed in a cell containing both *T. californicus* and *Paratetranychus coiti* fed only upon the Tydeid. When isolated with *P. coiti*, *Metatetranychus citri* and *Tetranychus sexmaculatus* Riley the Typhlodromids died within 2 or 3 days. So far, we have been unsuccessful in rearing *T. conspicuus* on any plant-feeding mites other than *T. californicus*.

Typhlodromus longipilus Nesbitt also occurs on both citrus and avocado trees. Experiments are now in progress to determine the food range of this mite. At the present time it has been observed to feed on both *Paratetranychus coiti* and *Tetranychus bimaculatus* Harvey. When isolated with *Tydeus californicus* the Typhlodromids died without feeding.

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Typhlodromus sp. near *finlandicus* has been found only on avocado trees. It has been observed to feed on *Metatetranychus citri*, *Paratetranychus coiti*, *Tetranychus sexmaculatus*, *Tetranychus bimaculatus*, and *Aceria sheldoni*. *Typhlodromus* sp. when isolated with *Tydeus californicus* was not observed to feed, although on several occasions it caught the pallid mite and appeared to attempt to insert its chelicera but seemed unable to pierce the body covering. After several attempts on various areas of the body, the Tydeid was released. Within 3 or 4 days after isolation with *T. californicus* the Typhlodromid mites died. A mature female predatory mite was placed in a cell which contained all four species of Tetranychids enumerated above. The female showed no preference in her choice of food. Several times during the day she was observed catching first one of the above and partially sucking out the body juices, and then within a short period of time would catch an altogether different species and partially extract its body juices.

Typhlodromus similis (Koch) has also been collected only on avocado trees; with the exception of several specimens found on an apple tree in an avocado grove. At present this species is known to feed upon *Paratetranychus coiti* and *Tetranychus bimaculatus*. Experiments are now being conducted with other plant-feeding mites. The food habits of the three remaining *Typhlodromus* species (*masseei* Nesbitt, *pomi* (Parrott)? and an undescribed species) have not been studied.

It is interesting to note that all of the above mentioned predatory mites, with the exception of *Typhlodromus conspicuus*, would not feed on *Tydeus californicus*. None of the mites studied were observed to feed on *Brevipalpus* mites. The predaceous mites mentioned that fed on both *Metatetranychus citri* and *Paratetranychus coiti* were readily transferred from avocado leaves to citrus fruit and back to avocado leaves without any apparent detrimental effects. This appears to indicate that these mites are capable of living on a variety of host plants.

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Injury to Pepper Plants by the Pea Leaf Miner

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Extensive injury to seedling pepper plants by the pea leaf miner, *Liriomyza langei* Frick, was noticed in May 1953 at Los Alamitos, in Orange County, Calif. Adults of this pest emerging from volunteer sugar-beet plants at roadsides and fence rows were puncturing the primary, or cotyledonous, leaves so severely that many of them turned brown and died. Larvae of this leaf miner also developed in many primary leaves and later entered secondary leaves, causing them to curl (fig. 1).

Several species of flies of the genus *Liriomyza* have been observed puncturing the leaves of plants so extensively as to give them a gray appearance. This type of puncturing has been noted on peas, sugar beets, tomatoes, peppers, spinach, cauliflower, and weeds of the genera *Chenopodium*, *Amaranthus*, and *Atriplex*.

FIG. 1.—Seedling pepper plants damaged by the pea leaf miner. Undamaged plant at right.

Since leaf punctures are usually many times more numerous than leaf mines, it has been assumed that much of the puncturing is done for purposes other than oviposition. Tilden (1950) observed repeated insertions of the ovipositor of a leaf-mining fly in leaves of *Baccharis pilularis* without deposition of eggs. The females fed on the exudate. Speyer (1950) found that males of the tomato leaf miner, *Liriomyza solani* Hering, fed only on diluted syrup, and that females fed principally on the sap from punctures made in the leaves with the ovipositor, although syrup was occasionally taken at midday when the temperatures were high.

Peppers are not a natural host of the pea leaf miner. Only the primary leaves of the seedlings were punctured, and after the plants had set other leaves, no further puncturing or leaf mining by this species was observed except as described. Five hundred acres of chili peppers were affected, stunting of the plants being severe in part of the acreage and mild in other parts. Economic loss was due to this stunting and to the cost of replacing missing plants.

Further information on the nature and extent of injury by these flies was obtained from an experiment arranged by the junior author. This was done by caging six 2-foot sections of double pepper rows planted especially for the experiment. The cages, covered with fine-mesh wire screen, were put in place as soon as the plants emerged, for protection against fly damage. Six days later, but before the secondary leaves had developed, 15 flies of the pea leaf miner were liberated in each of four of the cages. Two cages were free of flies. Extensive puncturing of the leaves was soon noticeable on plants in cages containing flies. After 3 weeks, when the plants had reached the transplanting stage, the cages were removed. Plant stunting was apparent as

a direct result of fly punctures in the primary leaves. Damaged plants were about half as large as undamaged ones. The dry weight of 10 plants from each of the fly-infested cages ranged from 10.1 to 12.1 and averaged 10.8 grams, compared with 22.9 and 24.3 grams for the plants from the two check cages. This was a reduction of 54 per cent in plant growth due to leaf miner attack.

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Control of Injury by Western Corn Rootworm Adults[1]

C. C. BURKHARDT[2,3]

The adults of the western corn rootworm, *Diabrotica virgifera* Lec., feed upon every part of the growing corn plant above ground. Although leaf feeding often is quite extensive, the most detrimental injury is to the silks. Considerable numbers of beetles were observed feeding on newly emerging silks during 1953. Where the beetles were abundant, all the silks were severed closely at the tips of the ears. When clipping of silks occurred at silk emergence, incomplete fertilization of the ovules occurred which resulted in ears sparsely covered with kernels (Fig. 1).

Injury to the ear was not confined to the destruction of the silks. Frequently, the well formed kernels at the tips of the ear were fed upon for a distance of 2 inches posterior to the tip of the ear.

It was estimated that many corn plants in north central-Kansas harbored more than 100 beetles each, particularly those plants on which the tassels were emerging. Populations of such magnitude made control measures necessary.

The western corn rootworm is an insect that

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[3] Acknowledgment is made to P. H. Marvin of Hobaugh and Marvin Agricultural Chemicals, Wichita, Kansas, for his assistance in making arrangements for aerial applications.

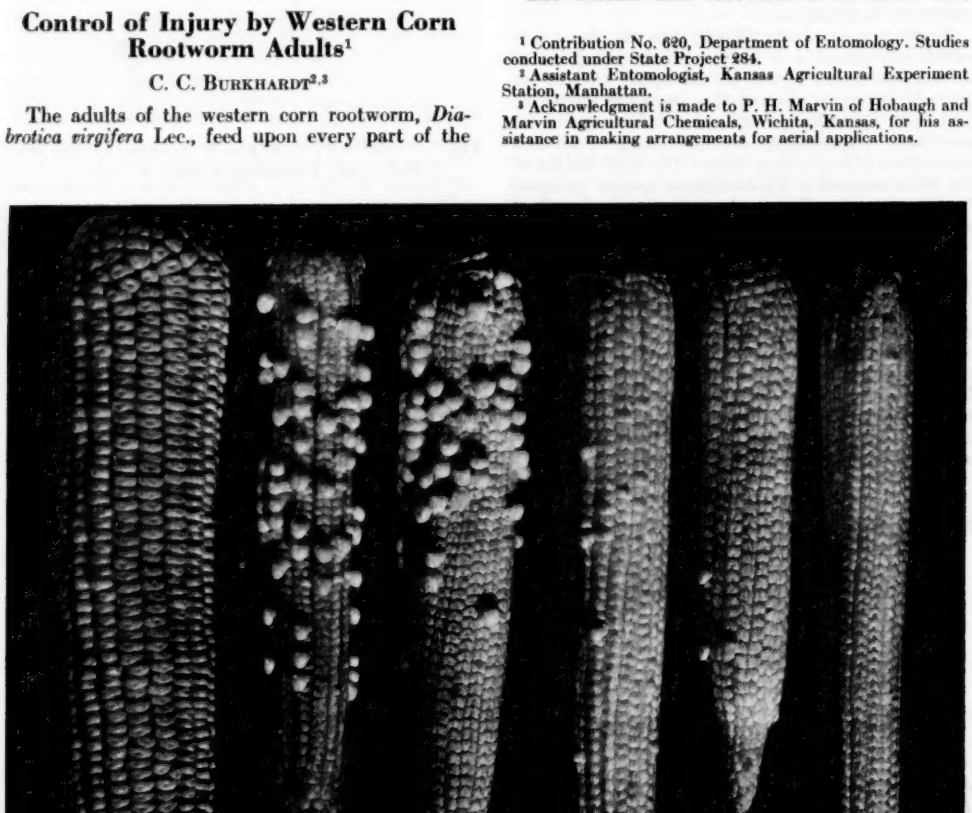

FIG. 1.—A comparison of pollination resulting from (left) an absence of Western corn rootworm beetles and (right) various degrees of injury caused by an abundance of beetles at tasseling and silking time.

should normally be controlled in the larval stage. Frequently, however, the adults emerge from the soil in infested fields and move into nearby heretofore uninfested fields. Here they often cause serious damage to silks; in addition they oviposit in these fields giving rise to a new crop of corn rootworms the following spring. If beetles are extremely abundant and become a threat to pollination as they did in so many fields in Jewell and Republic counties in 1953, control of adults becomes necessary.

Hill *et al.* (1948) found that aerial applications of a 3 per cent DDT dust applied at the rate of 25 to 30 pounds per acre gave excellent kills of rootworm adults in Nebraska. Furthermore, field observations indicated that such treatments reduced rootworm populations so effectively that lodging was of little consequence during the succeeding season.

Approximately 3,000 acres of corn were treated by aerial application for the control of the corn rootworm beetles in Kansas during 1953. An emulsion of DDT was used rather than a dust because most aerial applicators are not equipped to apply dusts and prefer to work with emulsions. The rate of 2 pounds of technical DDT per acre was used rather than any lower rate, to increase the length of residual action and thereby give protection against later emerging beetles. One gallon of undiluted 25 per cent emulsifiable concentrate DDT was applied per acre. Plants were carefully checked for distribution of spray particles. An even and satisfactory coverage was obtained without leaf burn.

RESULTS.—Counts of beetles were made before and after treatment in a commercially sprayed field near Scandia, Kansas. Prespray counts were made on 112 plants, examined in groups of 5 consecutive plants, each group taken at random across the field. The number of live beetles per plant ranged from 10–70, with an average of 34 beetles per plant (Table 1).

Table 1.—Results (after 12 hours) of spraying with 2 pounds of technical DDT per acre for control of the western corn rootworm. Scandia, Kansas. July 28, 1953.

COUNTS	PLANTS EXAMINED	LIVE BEETLES		DEAD BEETLES	
		Total	Av. per plant	Total	Av. per plant
Prespray	112	3841	34	0	0
Postspray	57	89	1.5	1886	33

A count was made 12 hours after treatment and the results obtained are summarized in table 1. The number of dead beetles ranged from 1 to 103 per plant, averaging 33. An average of 1.5 live beetles, or a range from 0 to 5, were recorded after spraying. This would indicate that an average of 95.4 per cent of the adults had been killed 12 hours after application of the insecticide. Dead beetles were found on the plants and on the ground. It was noted that 8 hours after application there were great numbers of moribund beetles, however, 4 hours later they were dead. A 36-hour postspray count showed virtually 100 per cent dead beetles. Where beetles were abundant, and where it was felt that spraying would be necessary, the application of insecticide was usually made about the time that the field was largely in tassel or when the first silks began to appear.

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Evaluation of Trunk Sprays against Peach Tree Borers in Delaware[1]

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For some years, especially since the advent of DDT-trunk spraying, more and more complaints have been received from Delaware orchardists conserning borers in peach trees. Smith (1951), in New York, showed that DDT was not effective against the lesser peach tree borer, *Syanthedon pictipes* (G. & R.), although it did control the peach tree borer, *Sanninoidea exitiosa* (Say). In recent years both species have become more abundant in Delaware. Although DDT is ineffective against the lesser peach tree borer, other factors must be responsible for the increased numbers of the peach tree borer. An examination of local spraying practices provides some evidence as to the reasons for the increase of the latter species.

Over the years, paradichlorobenzene has been used routinely by all commercial growers. Normally, it was applied in September during the period between the completion of Elberta peach harvest and the beginning of the late-apple harvest. Thus, its use fitted very well into common farming practices. However, considerable labor was required to prepare the soil around the trees and to apply the paradichlorobenzene. The opportunity to achieve the same ends, at much less cost, by spraying with DDT two or three times during the season was welcomed by practically all orchardists.

For several reasons, very few producers adhered strictly to the suggested program of trunk spraying, since it interfered with the harvest of early apples and peaches. Also, depending upon the variety, one and sometimes two of the sprays were scheduled at times when the trunk was more or less obscured by the heavily-laden branches. Often, this resulted in only one or two sprays being applied and these, not at appropriate times but at the convenience of the grower.

An experiment, at the Georgetown, Delaware, Substation, was designed to evaluate several insecticides as trunk sprays. Two rows of 4-year-old peach trees (rows 12 feet and trees 4½ feet apart), separated by 22 feet from an older peach orchard were selected for tests. The previous year the older planting was heavily infested with both the peach tree borer and the lesser peach tree borer. Accordingly, there was reason to believe that both species would be present in the rows utilized for the experiment. The trees under test ranged from 2¾ to 4 inches in diameter at the soil surface. Treatments were randomized and each one replicated three times. Ten trees, five in each row, constituted a replicate. Thus, 30 trees, 15 in each row, comprised one treatment.

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[2] Research Professor, Entomology; with the assistance of Charles A. Triplehorn and Don H. Lewis.

METHODS.—The materials were applied with a Bean sprayer operating at a pressure of 500 p.s.i., using a single-nozzle gun. The larger branches above the crotch and all sides of the trunk were thoroughly sprayed. Particular care was taken to direct the full force of the spray toward the base of the tree. This loosened and cleared away the accumulation of gum and frass that is always present on a heavily-infested tree. Each tree received three-fourths of a gallon of spray per application. The insecticides and dosages used are shown in table 1. Each toxicant was applied alone five times during the summer, but when the sticker was included only three applications were made.[3]

The dates chosen for application of the trunk sprays were based on information obtained by MacCreary (1951) on adult emergence of both the peach tree borer and the lesser peach tree borer. Records for that year showed that peach-tree-borer adults emerged from June 6 to September 14, while those of the lesser peach tree borer emerged during the period May 7 to September 25. Fifty-eight per cent of the peach tree borer moths emerged in August. Forty-six per cent of the lesser peach tree borer adults emerged in June. With the exception of a few that appeared in May, the remainder were divided almost equally among the months of July, August and September.

Since the trees had been planted for experimental use by the Department of Horticulture and had served their purpose, it was permissible to pull them for examination. This allowed a very accurate count of the larvae, particularly those below the soil surface. All borers were collected and returned to the laboratory, where they were identified by H. E. Milliron.

The anticipated infestation by the lesser peach tree borer did not materialize. The Horticulturist, in charge of the mature orchard adjoining the test plots, had been much concerned about the damage caused by this species to the upper trunk and scaffold branches, and had treated thoroughly all bark lesions with an oil-paradichlorobenzene mixture. The clean-up was so complete that infestation by this species was practically eliminated. Only 5 of 542 larvae proved to be the lesser peach tree borer.

Five trees (half of each replicate) were examined for borers in the fall of 1952 and the remaining trees, in the spring of 1953. The choice of trees for the fall inspection was made arbitrarily. One entire row was pulled, leaving the other one for the spring counts.

RESULTS.—The results of trunk spraying for control of the peach tree borer are summarized in table 1. The winter mortality is of particular interest. In the fall, there was an average of 27 larvae per tree in the unsprayed check; by the next spring, the number had decreased to nine, or an average of 18 borers per tree for the two examinations. This reduction in numbers from fall to spring is evident, also, in all of the treatments.

Any treatment that reduces the borer population to less than one larva per tree, under conditions that allow the development of 18 per tree in the unsprayed check, should provide satisfactory control for the commercial grower. An examination of the data in table 1 shows that all materials, whether applied three times with sticker or five times without, reduced the population of borers to 0.6 larva or less per tree. Without exception, there was a very slight increase in borer infestation in those plots receiving but three applications of toxicants. However, these differences are so minute that it is considered impracticable from the growers' point of view to include the two additional sprays. The conclusion seems warranted that three applications of any of the materials tested, with an adhesive added, should provide adequate commercial control. To obtain such results the sprays must be properly timed and thoroughly applied.

Table 1.—Results of trunk spraying for control of the peach tree borer.

TREATMENT[1]	NUMBER OF SPRAYS	NUMBER OF LARVAE PER TREE		
		Fall, 1952	Spring, 1953	Average[2]
DDT, 8 lbs./100 gals	5	0.13	0.00	0.06
Same plus sticker, 2 qts.[3]	3	0.80	0.20	0.50
BHC, 4 lbs./100 gals.	5	0.00	0.00	0.00
Same plus sticker, 2 qts.	3	0.06	0.00	0.03
Parathion, 2 lbs./100 gals.	5	0.00	0.00	0.00
Same plus sticker, 2 qts.	3	0.20	0.13	0.16
EPN-300 1½ lbs./100 gals.	5	0.46	0.06	0.26
Same plus sticker, 2 qts.	3	0.73	0.53	0.63
Dieldrin, 2 lbs./100 gals.	5	0.00	0.20	0.10
Same plus sticker, 2 qts.	3	1.06	0.13	0.60
Unsprayed check	—	27.10	9.00	18.00

[1] Dates of application—May 27, June 17, July 10, July 31 and August 21. Plots receiving insecticides and sticker were treated only three times (May 27, July 10 and August 21).

[2] Average of 30 trees.

[3] An experimental sticker developed by The National Sugar Refining Company, presently referred to as *National Sticker*.

SUMMARY.—DDT, BHC, parathion, EPN-300 and dieldrin were each applied five times to 30 trees (three replicates) for control of the peach tree borer, *Sanninoidea exitiosa* (Say). The same insecticides, with *National Sticker* added, were also applied three times. Half of the test trees were examined in the fall of 1952 and the remainder, in the spring of 1953. The 30 unsprayed trees averaged 18 larvae per tree, while in no case did any treatment average more than 0.6 larva per tree. Five applications of any of the materials provided slightly better control than three applications with the sticker included. However, the increased kill of borers was not sufficient to justify the expense of the two additional applications. Any one of the toxicants should provide good commercial control of the peach tree borer, when the sprays are properly timed and thoroughly applied.

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[3] A treatment with three applications of each toxicant without sticker was omitted, because both research and grower experience had shown such a schedule inadequate.

The Toxicity of Various Insecticides to *Chrysops discalis*

A. R. ROTH, *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*

The Tabanidae are serious pests of man and his domestic animals. Despite numerous efforts, no entirely satisfactory method has been found for controlling these pests by means of insecticides.

In 1953 several insecticides were tested in topical applications on the deer fly, *Chrysops discalis* Will., in the Summer Lake area in Oregon, where this species is an important pest. Gjullin & Mote (1945) and Roth *et al.* (1948, 1950) have reported on the biology, incidence, and distribution of this and other species found in this area.

The deer flies used in these tests were collected with a net over meadow lands and alkali flats near the site of emergence. Although of unknown age when treated, all flies were captured the day of treatment, and all were females. The flies were anesthetized with carbon dioxide and treated with acetone solutions of the insecticides, applied with a small syringe having a micrometer gauge attachment. After treatment the flies were kept in clean 1-quart containers with screened ends. The containers were placed on an inclined base to facilitate air circulation, and cotton pads saturated with sugar solution were placed on the upper screens to provide food for the flies. Twenty female flies were used in each test, and mortality counts were made after 24 hours. The results are presented in table 1.

Lindane, the most effective insecticide tested, gave 100-per cent kill at 0.05 microgram per fly and required approximately 0.035 microgram for an LD-90. Toxaphene was the least effective. About 13 times as much toxaphene as lindane was required for an LD-90. EPN, malathion, Diazinon, and other organic phosphorus compounds were less effective than were most of the chlorinated hydrocarbons.

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DDT Fails to Control *Erythroneura lawsoniana*

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Since the general adoption of DDT by apple growers in the Middle West, the numbers of leafhoppers have dropped to a low point. Even light deposits seem to have been effective. In the summer of 1953, however, a grower near Paducah, Kentucky, reported that he was unable to control leafhoppers in his orchard with DDT.

This orchard consisted of mature trees. Heavy populations of leafhoppers, mostly adults, were present, and severe injury had occurred to the foliage, along with limited spotting of the fruit. Although the sprayer used by the grower delivered only 7 gallons per minute at a pressure of 300 pounds per square inch, control of pests other than leafhoppers, such as scab and codling moth, was satisfactory. Seven cover sprays of DDT, 2 pounds of 50-per cent material to 100 gallons, had been applied during the season, the last application between August 10 and 15. In September the grower stated that leafhoppers had built up in July and that he has not been able to reduce their number materially with sprays applied after that time. Residues of DDT present on the leaves on September 8 still averaged 3.8 micrograms per square centimeter, indicating that leafhopper control should have been satisfactory.

Specimens of the adult leafhoppers present in the orchard were identified as *Erythroneura lawsoniana* Baker,[2] one of the more common species found on

[1] W. D. Armstrong, Kentucky Agricultural Experiment Station, assisted in these experiments.
[2] Identified by D. A. Young of the Entomology Research Branch, Agr. Res. Serv., U.S.D.A.

Table 1.—Toxicity of various insecticides to topically treated deer flies. 3 to 6 replicates.

INSECTICIDE	PER CENT MORTALITY[1] IN 24 HOURS AT INDICATED MILLIGRAMS PER FLY										ESTIMATED	
	0.001	0.005	0.01	0.025	0.05	0.1	0.25	0.5	0.75	1.0	LD-50	LD-90
Lindane	18	56	80	—	100	—	—	—	—	—	0.004	0.035
Endrin	—	20	57	—	87	93	100	—	—	—	.009	.08
DDT	—	—	20	67	74	82	—	100	—	—	.02	.25
Dieldrin	—	20	29	—	74	91	100	—	—	—	.02	.095
Methoxychlor	—	—	28	43	73	92	100	—	—	—	.03	.09
Aldrin	—	—	21	—	55	82	100	—	—	—	.04	.17
Heptachlor	—	—	12	27	60	87	100	—	—	—	.04	.2
EPN	—	—	23	—	55	89	100	—	—	—	.048	.12
Isodrin	—	—	34	—	46	70	—	100	—	—	.06	.17
Chlordane	—	—	10	—	47	67	—	80	97	100	.06	.65
Bayer 22/190[2]	—	—	18	—	33	70	—	95	97	100	.065	.42
Diazinon[3]	—	—	27	—	32	54	82	100	—	—	.09	.36
Bayer 21/199[4]	—	—	42	—	46	51	—	73	78	97	.09	.91
Q-137	—	—	15	—	38	44	—	95	100	—	.12	.4
Malathion	—	—	—	—	23	41	85	100	—	—	.13	.33
Toxaphene	—	—	21	—	32	39	—	93	100	—	.18	.48

[1] No mortality in checks.
[2] 0,0-diethyl 0-3-chloro-4-nitrophenyl thiophosphate.
[3] 0,0-diethyl 0-(2-isopropyl-6-methyl-4-pyrimidinyl) thiophosphate.
[4] 3-chloro-4-methylumbelliferone 0,0-diethyl thiophosphate.

apple in the Midwestern States. Although no specimens from this orchard have been identified previously, it seems probable that the same species was present prior to 1953.

On September 8 experimental applications of DDT, nicotine sulfate, and parathion were made to uniformly infested apple trees in this orchard. Since replication seemed unnecessary, each test consisted of a single tree isolated from other sprayed trees. The grower's spray equipment was used, and 25 gallons of spray were applied per tree with a single-nozzle gun having an $\frac{1}{8}$-inch orifice. The ground area adjacent to the tree was also sprayed to reduce immediate reinfestation. A drop cloth was placed under a portion of each tree and left 18 hours for observations on results.

Visual examination of sprayed trees after approximately 1 hour indicated that nicotine sulfate at 1 pint to 100 gallons had caused the greatest immediate kill of leafhoppers, that 50-per cent DDT at 1 and 2 pounds had not killed a substantial portion of the leafhoppers, and that 15-per cent parathion at 1 pound had caused little immediate kill.

Examinations made early the next morning, while the leafhoppers were still quiescent from night temperatures, showed that nicotine sulfate had been the most effective and would have substantially reduced the population had all portions of the orchard been sprayed. Neither DDT nor parathion was effective.

From the results obtained it was concluded that the strain of *Erythroneura lawsoniana* present in the orchard may have built up resistance to DDT, since the grower using the same spray schedule had experienced no difficulty in controlling leafhoppers prior to 1953.

Residue determinations on leaf samples as soon as the deposits had dried showed 10.1 micrograms per square centimeter from the 1-pound and 16.1 micrograms from the 2-pound applications of DDT and 1.2 micrograms from parathion.

Cutworm Control in Muckland Carrots

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In June and July cutworms of *Agrotis* sp. regularly attack the crops on the mucklands near Elba, New York. Present control methods involve periodic dusting, spraying, or baiting during this period. These methods are often futile due to the high winds at this time of year which continually blow the "top muck" around, thus covering or blowing away the soil particles on which the toxicant has settled.

The observations reported herein were made during a test designed to control the first generation of the carrot rust fly, *Psila rosae* (F.). In this test the insecticide treatments were applied using a drench-type planter which consisted of six Planet Jr. planters mounted side by side 15 inches apart. On top of the planters a 100 gallon tank was mounted with hose connections leading into the shoe of each row planter. As this unit moved through the field the seed and furrow of each of the six rows was automatically drenched with the contents of the tank. The flow of liquid was adjusted by regulating the opening of a valve in each hose lead. By closing the tank outlet valve while proceeding to plant untreated areas could be arranged as desired.

Parathion, from a 42 per cent liquid concentrate[1] containing 4 pounds technical parathion per gallon, was applied at 1.5, 2, and 3 pounds of active ingredient per 100 gallons per acre. Each treatment was applied on six rows 1,452 feet long and replicated two times. Two untreated areas, six rows by 50 feet, were left in each replication of each treatment. The treatments were applied May 4, 1953. On May 20 counts were taken which revealed no differences in seedling emergence.

When the first samples of carrots were pulled in mid-June it was apparent that the carrot rust fly injury would be masked by a heavy infestation of a root knot nematode, *Meloidogyne* sp., and thus the experiment was abandoned for that purpose. During late June, however, there was extensive cutworm activity throughout the entire muckland area. At that time it was observed that the untreated areas were nearly free of carrots while in the treated portions of the field carrots were as abundant as needed to produce a crop. Further investigation revealed that many cutworm larvae could be found in the soil in the untreated areas while an extensive search of the treated rows yielded only four larvae which appeared to be suffering from the effects of insecticide poisoning. This field received no other treatment and the treated portions produced a good stand throughout the season.

From these observations it is felt that a more efficient and practical method of protecting many crops from cutworms may be utilized, particularly on muckland.

[1] *Orthophos 4 Spray*®, California Spray-Chemical Corp.

The Old House Borer in Massachusetts[1]

W. B. BECKER, *Massachusetts Agricultural Experiment Station, Amherst*

This cerambycid beetle, *Hylotrupes bajulus* (L.), which produces a powder post beetle type of injury in the sapwood of well seasoned coniferous wood, has been reported a serious pest of wooden structures in Europe for many years. Although it has also been known in the United States for a number of years, apparently being an introduction from abroad, there are relatively few published reports on the subject here.

The Massachusetts Experiment Station has discovered injury by this pest 19 times in the state since 1939. In 14 instances, actual specimens of the insect[2] were obtained, and in five other cases the injury to seasoned coniferous wood was so typical it seemed certain that this species was involved. Some infested buildings were quite old, at least one being of some historic interest. One house was reportedly built about 1685. Typical complaints of home owners usually included: (1) discovery of injured wood (Fig. 1, A); (2) occasional dropping of powdery "sawdust"; and (3) appearance of a few

[1] Contribution No. 918 of the Massachusetts Agricultural Experiment Station, Amherst.

[2] Most specimens were identified by Dr. W. H. Anderson or Dr. B. E. Rees, Section of Insect Detection and Identification, Entomology Research Branch, at Washington, D. C., but a few were identified by the author. Three pairs of ocelli on a cerambycid larva taken from old seasoned coniferous wood that shows a powder post beetle type of injury is strongly indicative of this species.

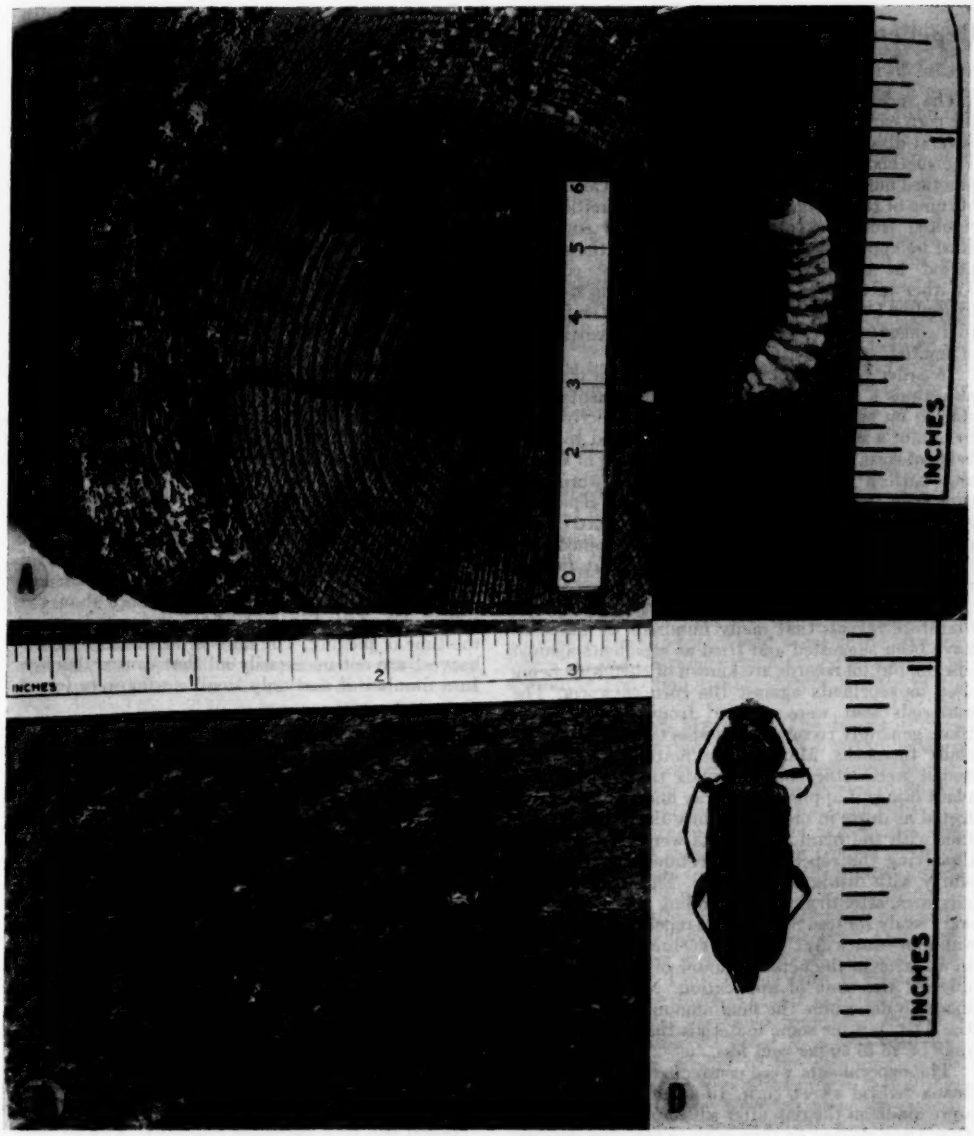

FIG. 1.—The old house borer and its injury. A. Cross section of beam showing sapwood portion injured by larvae. B. Larva. C. Typical oval exit holes of adults at surface of infested wood. D. Adult.

oval exit holes on surface of wood (Fig. 1, C). In a few instances, people also reported hearing "gnawing" or "clicking" sounds in infested walls, an occurrence that is commonly reported in the literature.

In all known instances, except one, the infestations occurred between the vicinity of Worcester and the Atlantic coast. Towns where larvae or adults (Fig. 1, B and D) were taken include: Acushnet, Amesbury, Andover, Brockton, Chelmsford, East Weymouth, Fairhaven, Ipswich, Norfolk, Norton, Still River, and Nantucket Island. Typically injured wood was collected at Middleborough, Millbury, Provincetown, Watertown, and Westford. The one infestation found outside this area was at West Springfield in the Connecticut River Valley. At that location, a number of adults emerged from some wooden buildings at the old New England "village" of "Storrowtown" on the grounds of the Eastern States Exposition. Storrowtown is a group of old buildings collected at different points in New England and reassembled as an exhibit on the fairgrounds.

This species may be more widespread in Massachusetts than our present records indicate. It may become a much more common pest. Certainly it is a problem for those who own infested buildings.

Repellents for Corn Earworm Control[1]

WILLIAM F. CHAMBERLAIN[2]

The most generally used method for control of the corn earworm is the use of a DDT-oil emulsion. Several disadvantages of this spray are recognized. The method is relatively expensive and its use is practical only on sweet corn or seed corn. Occasional burning of the foliage or reduction in pollination has resulted from the spray. The DDT-oil emulsion must be applied from 2 to 5 times during the silking period in order to obtain satisfactory control. Another method of control, that of using a brush to apply a DDT dust to the silks, has been employed to a considerable extent. This method is costly and of limited applicability.

In order to attempt to overcome some of these objections a series of preliminary experiments were started on the use of repellents. The objective was to obtain a material that could be applied to large fields of corn by airplanes at the beginning of silking and with a single application obtain worm-free ears. The tests that were conducted with repellents showed that the corn earworm can be repelled by the use of suitable materials. The results obtained during 1953 are reported with the hope that further research on this subject will be stimulated.

METHODS AND MATERIALS.—A review of the literature reveals that many hundreds of materials have been suggested and tried as repellents against insects, but no records are known of chemicals being used as repellents against the corn earworm. The materials that were selected from this list were those generally recognized as insect repellents, especially to moths. Many of the materials that were tested were either oils or solids that could cause plant injury if applied as a spray and were therefore tested as dusts in order to reduce their surface contact with the plant. The dusts were formulated by dissolving the repellents in acetone and making a slurry with distomaceous earth. The repellent dust mixtures, after drying and grinding when necessary, were ready for use. Some of the repellents tested had vapor pressures nearly that of acetone which resulted in an error in the actual amount of repellent in the dust at the time of application. No attempt was made to determine the final amount of repellent in the dust, but for some materials the actual amount may be 25 to 50 per cent less.

The experiments were conducted in two fields of Ioana hybrid sweet corn. In June the treatments were made on the day after silks appeared or at the time they started to turn pink. Each dust was applied with a shaving brush to 25 silks each day. Each ear was labeled with the material applied. Only one application was made to each ear, but it was necessary to continue applications for 4 days in order to have all the ears in the same condition of silk. The plots were therefore overlapping with no definite boundaries between test materials. One repellent followed another in the row so that on days when a large number of silks was in satisfactory condition the plots would be shorter than on days when there were less silks. Checks were established throughout the field. Results are shown in table 1.

In August the plots were two rows wide and 50 feet long. Two plots were used for each material tested. Data on the check ears were obtained from four plots. In this experiment the dusts were applied with a small puff-type duster to the individual silks. Dusting was started on the third day of silking.

Table 1.—Single application treatments with dusts for corn earworm control. June, 1953.

Treatment	Total		Per Cent	
	Ears	Worms	Ears Uninfested	Pollination
Allethrin, 0.5%	77	178	0.0	81
Pyrethrum, 2.0%	72	129	1.4	10
Benzyl chloride, 50%	61	93	0.0	45
Pyridine, 50%	60	103	1.7	90
Formaldehyde, 50%	56	89	1.8	81
PDB, 50%	61	85	0.0	81
Turpentine, 50%	64	95	17.2	72
2-napthol, 50%	58	82	6.9	50
Pine oil, 25%	61	72	3.3	80
Parathion, 1.5%	77	193	7.8	80
Parathion, 15%	71	37	52.0	83
Diazinon, 2.5%	42	47	21.0	85
Diazinon, 25%	56	15	75.0	92
Checks	126	253	0.0	93

Applications were made on August 17, August 20, and August 24. Silks that had attained the pink stage were dusted on each date so that some silks received three applications while others received only one application of the dust. Results are shown in table 2.

DISCUSSION.—The tests with repellents were subject to very severe infestations as more than two worms were found in each of the untreated ears at the time of picking. The number of worms found at harvest are not necessarily all that caused damage. In a number of ears only small worms were found,

Table 2.—Multiple application treatments with dusts for worm control in sweet corn ears. August 1953.

Treatment	Total Ears	Number of		Per Cent Marketable Ears
		Armyworms	Corn Earworms	
Turpentine, 40%	131	33	192	24.4
Pine tar oil, 40%	163	102	274	7.9
Triethanolamine, 25%	131	107	160	5.4
Parathion, 15%	119	1	30	85.6
Diazinon, 25%	98	2	37	71.3
Ovotran, 25%	164	119	255	15.2
Checks	202	195	292	7.9

but large areas of the kernels had been destroyed by more mature worms. Six of the materials tested repelled the corn earworm somewhat with at least one ear free of worms. Only the turpentine-impregnated dusts showed a degree of repellence that warrants further testing. The 17-per cent noninfested ears obtained in the first experiment show that the corn earworm was repelled by the use of this material. If the infestation had averaged one worm or less per ear, a much higher per cent of noninfested ears would have resulted. All worms found in the ears in the June experiment were corn earworms. The control obtained with the use of turpentine dust was better than that shown by the 1.5-per cent parathion dust and approximately equivalent to the 2.5-per cent Diazinon dust. Neither the pyrethrum

[1] Technical Contribution No. 220 from the Department of Entomology and Zoology, South Carolina Experiment Station, Clemson.

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nor allethrin dusts gave any degree of control. The most injury to pollination was caused by the pyrethrum dust. This injury was probably caused by the synergist, n-Octyl sulfoxide of Isosafrole in the formulation. Pollination was affected by all the materials used in the June experiments. In the August experiments, however, there were no appreciable differences in pollination between the treated and untreated ears. The application of dusts with a brush caused some reduction in pollination that would not have resulted from applications made with the puff duster.

The application of dusts to the silks caused them to turn brown faster than normal, but none of the materials tested showed any burning of the shuck or leaves when applied as a dust. Further tests with benzyl chloride are not recommended as this material is a very strong skin irritant. In table 2 the marketable ears include those ears noninfested or with no more than 1 inch of the tip of the ear damaged or infested by small worms. Of the repellents tried in August the turpentine showed some degree of control while the pine oil and triethanolamine did not. The turpentine dust was slightly better than the 25-per cent *Ovotran* dust. Under field conditions the *Ovotran* evidently is not a satisfactory ovicide even at the high concentration used. The 40-per cent turpentine apparently had no effect on the number of corn earworms per ear, but greatly reduced the number of fall armyworms.

SUMMARY.—Preliminary experiments on the use of several repellents for the control of the corn earworm showed that 40 to 50 per cent turpentine gave 17 per cent worm-free or 24 per cent marketable ears. In the untreated checks no ears were worm-free and only 7.9 per cent were marketable. Better control may be possible in a large field test as a result of the cumulative effect of the whole treated field. Other repellent materials may prove to be more effective than turpentine. The incorporation of turpentine and other materials into dusts eliminated the injury resulting from direct application or as emulsions with water.

Termites in Citrus on Newly-Cleared Brushland

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The desert damp-wood termite, *Kalotermes* (*Paraneotermes*) *simplicicornis* (Banks) has been considered a minor pest of citrus. Under certain circumstances, however, the insect has been known to become a serious pest of young trees near Weslaco, Texas. Bynum (1951) reported damage by the termite in the Lower Rio Grande Valley of Texas as well as the distribution in the dry-land areas, especially in recently-cleared brushland. Since more than 5,000 acres of young citrus was known to be subjected to varying degrees of attack, the problem was investigated in order that damage caused by these termites might be reduced.

During January, 1952, a citrus grower, north and west of Edinburg, Texas, complained of losing several young trees day after day as a result of termite attack. Such young trees usually showed symptoms of termite attack after considerable injury had been done to the root system. The grove provided an excellent opportunity to study the termite problem. It was planted to oranges and grapefruit in 1946 and 1947 immediately following the removal of brush. Cotton was interplanted for several years in order that the grower might receive some income from the land while the trees were growing to the productive stage. Termites were found around vegetation only in the tree row area. The pest was not found in the cultivated, or interplanted, area.

A real problem occurred when the trees were banked for freeze protection. Weeds had been allowed to grow between the trees within the row for wind protection for the trees and to reduce wind erosion. Such coverage had apparently been adequate to maintain the termites for the previous years. When the area between the trees became too dry, the termites no doubt moved toward the moist area around the trees which was kept from drying by tank-watering. It seemed apparent that in many cases, termite-infested soil was thrown about the trees while banking.

The first observable symptom was the withering of the leaves. When such trees were dug, usually the tap root was found to be cut off by termites below the main laterals. After the tap root had been severed, the termites would start feeding upward toward the trunk of the tree. Trees dug early at the first signs of the leaves withering, treated for termites and planted again were found to be capable of growing a new tap root. Dead wood in the area just below the main lateral roots must be considered an unhealthy condition for the future welfare of the tree.

MATERIALS AND METHOD.—The danger of freezing was not over during January but the banks of trees in every other tree row were removed to compare the treatment of three insecticides of banked versus unbanked trees. Six-foot watering rings were the basis from which dosages of insecticides were figured. Since 60 gallons of water seemed to be the necessary gallonage to distribute the diluted insecticide in the root zone of 14 to 15 inches in depth, dosages were figured for the distribution of 0.5, 1.0 and 2.0 pounds chlordane per 50 trees. Aldrin and parathion dosages were figured at one-fourth the above amounts. Tank trucks with a capacity of 1800 gallons were made available for application of diluted insecticide. The tanks were filled from a 5-inch head of water connected to a well with poor water. Thorough mixing of the solutions seemed assured as the tanks were filled in less than 3 minutes. Since watering was a necessary operation, additional cost of application was only that of the insecticide. A total of 478 trees was treated.

RESULTS.—A dosage of 60 gallons of water per tree penetrated to a depth of 20 inches for the banked trees. After 5 hours, the soil was found moist only within 8 to 10 inches of the tap root. The same amount of liquid penetrated to a depth of 14 to 15 inches to adequately disperse the insecticidal solution about the lateral roots of unbanked trees.

Of the treated trees, only six trees were found to have termites around the roots during the test period following application. Two, banked, check trees of a comparable number of trees per individual insecticidal treatment were killed by termites. Two dead, unbanked trees that were known to have had termites before treatment with the low dosage of parathion, were found to have termites 3 months later. Termites were found in June in one unbanked tree treated with the heavy dosage of parathion. The tree was fourth from the last tree treated with

the tank mixture which failed to either prevent damage or movement to the tree by the termite. Termites were found around the roots of one unbanked tree, treated with a low dosage of aldrin, at the close of the tests. At the same time, two unbanked trees, treated with the high dosage of aldrin, were placed in the doubtful category. One tree had termite damage symptoms while the other died of questionable causes. One low-dosage-chlordane treatment to an unbanked, dead tree, failed to stop the termites from working in the tap root just below the trunk. A banked tree, treated with the medium dosage of chlordane, was found on February 19th to have the tap root cut off. Although the top of the tree was small, the tree had recovered and had resumed growth.

Observations were made 20 and 77 days after treatment for termites around vegetation between the trees. The number of termites was roughly proportional to the amount of vegetation.

DISCUSSION.—Although termites might have been absent in the initial samples, the pest could have been present in areas under the tree where samples were not taken. However, any termites found during the observational period or at the conclusion of the tests indicated failure of the treatment. Records then indicated the kill of the termites initially, if present, and/or protection of the roots from termite movement from outside the watering rings.

Lateral water penetration in banked trees was found insufficient to allow the insecticide in solution to move closer than 8 inches of the tap root. The liquid, in the dosages applied, moved almost straight downward and about one-third the dosage moved below the lateral root zone. It seemed that if termites were present at the tap root when application was made, the liquid could not make contact at this point of attack in such loose soil around banked trees.

Once the insecticide was distributed in the root zone, subsequent waterings would be expected to dilute the insecticide by leaching. Such reduction in dosage would permit the termites to move in from vegetation outside the root zone. Since little or no rain fell during the 4 months following treatment and irrigation water was not available, subsequent treatment with insecticides was considered unnecessary.

The best indication of the comparative effectiveness of the insecticides against the termite was obtained on those trees that were dead at the beginning of the test. Such tree stumps could be removed easily and if found infested the treatment could be ruled ineffective against termites already in the trunk of the tree. However, the solutions might have failed to reach them in the trunk, particularly in banked trees.

SUMMARY.—Observations indicated that planting citrus near Weslaco, Texas on recently-cleared brushland is a poor practice, particularly in the drylands area with lighter soils. It was indicated that if such land was planted to row crops for at least 3 years with particular care being given to the removal of wood from the soil, the termite problem would be greatly lessened.

Lateral penetration of insecticidal solutions was found to be insufficient with banked trees to reach termites in the area just below the trunk. The distribution of insecticidal solutions below the lateral root zone was considered valueless. Rains or subsequent waterings would be expected to dilute the insecticide and allow termites to move from outside the rings when the residual insecticide became ineffective. Subsequent treatment might then be required.

Termites were found around the roots of six trees, 18 days or more after the application of certain treatments with parathion, aldrin, and chlordane. Termites were not found about the roots of trees treated with chlordane at a dosage of 1 pound, or more per 50 trees.

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Walnut Aphid Resistant to Parathion in Northern California

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C. C. CASSIL[2] and C. S. DAVIS[1]

One of the most alarming situations confronting economic entomologists is the selecting out or the development of resistance by insects to certain of the new insecticides. This turn of events threatens the beneficial and continued economical use of some of our key insecticides now used in control programs directed against given insects. In the course of walnut insect investigations conducted during 1953, a strain of walnut aphid, *Chromaphis juglandicola* (Kltb.), was encountered in the San Jose area that exhibited definite resistance to parathion. Attention was first called to the problem by a grower who found that he could no longer control the aphid with dosages of parathion that formerly resulted in excellent control. He first encountered the difficulty in 1952 and since then, in order to obtain control, he has had to gradually but constantly increase the dosage of parathion.

In order to determine the degree of resistance, tests were conducted in which the resistant San Jose strain was compared with a non-resistant strain collected at Walnut Creek, California. The two populations were compared by exposing aphids on walnut leaves to different amounts of a 0.5 per cent parathion dust by means of a vacuum bell jar duster. The procedure used was to count the aphids on freshly gathered walnut leaves, dust the leaves and then hold them for 4 hours at which time mortality counts were made. All tests were replicated and adequate checks were maintained.

The results obtained are shown in figure 1, as a log dosage—probit plot. It is seen that 140 mg. of the 0.5 per cent parathion dust was required for the LD_{50} level of the San Jose strain while only 20 mg. of the dust was required for the LD_{50} of the Walnut Creek strain. This indicates a sevenfold resistance to parathion on the part of the San Jose aphids. It may be further noted that the slope of the regression line for the resistant San Jose population is typically less steep than the line for the non-resistant Walnut Creek aphids.

In order to obtain additional information on resistance, a field test was conducted on the San Jose aphids. Treatments were applied with the latest model high capacity air-carrier sprayer. One block of trees was sprayed with parathion 25 per cent

[1] University of California, Berkeley.
[2] Niagara Chemical Division; Food Machinery and Chemical Corporation.

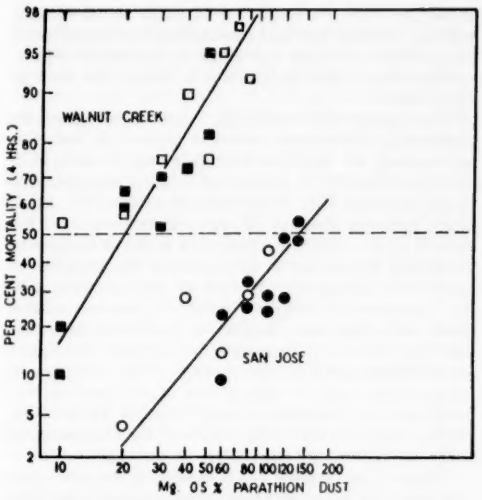

FIG. 1.—Log probit mortality curve for non-resistant Walnut Creek strain of the walnut aphid as compared with that of the resistant San Jose strain. Open squares and circles, tests run August 14, and solid squares and circles, tests run August 21.

wettable powder at the rate of 2 pounds per acre in 100 gallons of water. A second block was treated with 14 per cent nicotine dry concentrate at the rate of 9 pounds per acre in 100 gallons of water. The amount of parathion and water used was twice that normally recommended, while the nicotine dosage was increased from approximately 7 to 9 pounds, and the water from 50 to 100 gallons. The results are given in table 1.

Table 1.—Comparison of parathion and nicotine dry concentrate for control of the walnut aphid.[1]

TREATMENTS[2]	AVERAGE NUMBER OF APHIDS PER LEAFLET ON DATES GIVEN				
	Aug. 21[3]	Aug. 24	Sept. 4	Sept. 11	Sept. 17
25% parathion wettable powder—2 pounds	27.3	1.3	12.4	15.0	19.8
14% nicotine dry concentrate—9 pounds	27.3	0.4	0.5	1.0	1.9

[1] At San Jose, California, where resistance to parathion was shown.
[2] Approximate amounts applied per acre in 100 gallons of water.
[3] Before treatment.

Although the parathion resulted in a marked reduction in the aphid population, the kill was considered unsatisfactory, because for good control with parathion, the aphid population should be almost entirely eliminated from the treated area. This is believed to be necessary because of the adverse effect parathion exerts on natural enemies. The initial mortality obtained with the nicotine treatment was less than expected, but the control was good. The treatment exerted no marked harmful effect upon the natural enemies, and they proceeded to hold the aphid in check. The rate of increase in the parathion block would have been much more rapid if it had not been for a rather heavy invasion of predators which tended to curb the aphid population. The predator increase in this plot was unusually rapid.

The grower had a portion of the orchard not under experimentation treated by a commercial pest control operator. The dosage of parathion 25 per cent wettable powder needed to give satisfactory control was roughly 3 pounds per acre which is a threefold increase over the usually recommended dosage.

Specimens of the resistant San Jose strain and the non-resistant form from Walnut Creek were submitted to Professor E. O. Essig for study. He reported that he could not detect any morphological difference between the two strains.

Mold Control in Fly Rearing Media

DEWEY E. BORN, *Ohio State University, Columbus*

One of the problems connected with rearing house flies is that of mold formation in the larval media. When severe, such growths can destroy the developing maggots. This problem has been solved at the Ohio State University by the addition of a 1-inch layer of sand to the top of the jars of CSMA fly rearing media 48 hours after seeding with eggs. This time lapse is critical due to the fact that addition of sand at an earlier time will inhibit or prevent hatching.

Sand itself is not fungistatic or fungicidal. This has been shown by placing a layer of sand on jars of media which have not been seeded. In each case an abundance of mold was observed in the jar.

Unless overcrowded, the larvae are not found in the top portion of the media. It is in this area that the mold first appears. With the addition of sand the "working" depth of the media is increased and the larvae are active up to the sand layer. It is believed that the activity of the maggots in the upper portion of the media prevents the formation of mold.

The majority of last instar larvae will pupate within the sand layer. Collection of pupae is greatly simplified by sifting this upper layer through a number-10 sieve, which will pass most of the sand, leaving the pupae.

This method has also been used successfully for rearing stable flies. The procedure is the same as with house flies, with the exception of one additional step. To insure proper distribution of pupae in the sand layer, the sand must be moistened 1 day prior to the expected date of pupation, otherwise pupation will occur at the sand-media interface.

Effectiveness of Certain Insecticides against the Spiny Bollworm in Iraq

R. L. WALKER,[1] *Entomology Research Branch, Agr. Res. Serv., U.S.D.A.*, and HAIDAR SALEH HAIDARI, *Abu Ghraib Experimental Farm, Iraq*

The spiny bollworm, *Earias insulana* (Bvd.), is a pest of cotton in all cotton-growing countries from

[1] On leave of absence in Iraq with the Food and Agriculture Organization of the United Nations during 1952.

Thailand and India west to the Mediterranean Sea and in Africa. It has also been reported from Spain and Sicily. It is the major pest of cotton in Iraq. In some years losses in yield of seed cotton caused by this insect are undoubtedly as high as 80 per cent, and it is not unusual for an individual grower to lose all of his crop.

From 1937 through 1951 limited tests were conducted by personnel of the Entomology Department of the Abu Ghraib Experimental Farm in Iraq in an effort to find a chemical control for the spiny bollworm. Calcium arsenate, lead arsenate, sodium fluosilicate, barium fluosilicate, and a mixture of BHC and DDT were tested as dusts. It was reported (unpublished) that little or no control was obtained with these materials.

In 1952 two small-plot tests were conducted on the Experimental Farm to determine the efficacy of several chlorinated hydrocarbon insecticides applied as emulsion sprays.

MATERIALS AND PROCEDURE.—A Latin-square design was used in both experiments, with the untreated check area completely surrounding the experimental area.

In experiment 1 endrin and dieldrin were tested at 1.5 and 2 pounds of technical material per acre on plots 10 rows wide and 41 feet long. Eight applications were made between July 16 and September 28. In experiment 2 endrin was used at 0.5 and 1 pound, dieldrin at 1 pound, and toxaphene at 6 pounds per acre on plots 18 rows wide and 65.6 feet long. Eight applications were made between August 10 and October 13. Both experiments were conducted on Coker 100 Wilt cotton.

A 5-gallon pneumatic sprayer equipped with a pressure gauge was used to apply the insecticides. The spray boom was equipped with one nozzle per row, which delivered approximately 30 gallons of spray per acre when carried through the field at a normal walking rate and maintained at a pressure of about 60 pounds per square inch. Insecticide applications were made before 8 a.m. when the air was fairly calm.

The square and boll injury was determined by examining 100 squares and 100 green bolls selected at random on the four middle rows of each plot. In experiment 1, 14 records of injured squares were taken between July 20 and October 2 and of injured bolls between August 16 and November 12. One record of the bolls infected with boll rot fungi was made on November 5 by counting the number of such bolls found on 150 feet of row in each plot. In Experiment 2, eight records of injured squares were taken between August 16 and September 29, and six records of injured bolls between October 7 and November 12. One record of the number of pupae found on 24 square feet of soil surface was made at two locations in each plot on January 22, 1953. Yield records were obtained for experiment 2 only, by picking all the cotton in each plot.

FIELD CONDITIONS.—All cotton is grown under irrigation in Iraq, as there is no rainfall from June through October. Fields are usually irrigated about 15 times during the growing season, the last irrigation about the first of October. Owing to irrigation and climatic conditions, there are two distinct growth flushes, or periods of maximum fruiting, of the cotton plant. The first flush generally occurs during June and the second begins about the middle of August.

RESULTS.—The spiny bollworm was the only economic pest observed on cotton during the 1952 season. In experiment 1 endrin, at both rates of application, gave significantly better bollworm control than dieldrin as evidenced by the average per cent of square and boll injury (Table 1). There

Table 1.—Effectiveness of endrin, dieldrin, and toxaphene against the spiny bollworm. Abu Ghraib Experimental Farm, Iraq, 1952.

Treatment	Pounds of Toxicant per Acre	Average Per Cent of Injured—		Average Number		Pounds of Seed Cotton per Acre	
		Squares	Bolls	Of Rotted Bolls on 150 Feet of Row	Of Pupae per 48 Square Feet of Soil Surface	Total	Gain Over Check
Experiment 1							
Endrin	2.0	12.4	6.8	58	—	—	—
	1.5	12.2	6.2	68	—	—	—
Dieldrin	2.0	15.5	12.4	86	—	—	—
	1.5	16.4	12.5	72	—	—	—
Untreated check	—	35.9	50.1	307	—	—	—
Difference required for significance							
5% level		1.5	3.0	—			
1% level		2.4	4.5				
Experiment 2							
Endrin	1.0	11.1	4.7	—	7	1580	1249
	0.5	12.7	7.5	—	5	1369	1038
Dieldrin	1.0	22.3	21.4	—	17	1165	834
Toxaphene	6.0	19.7	17.4	—	15	1285	954
Untreated check	—	50.5	68.7	—	38	331	—
Difference required for significance							
5% level		5.0	7.3		8	158	
1% level		7.6	11.1		12	243	

was no significant difference in control between the two dosages of either insecticide. Both gave excellent control compared with that of the untreated check.

Field observations showed a positive relationship between the degree of injury caused by the spiny bollworm and the number of bolls infected with boll rot fungi. Apparently the penetrations of the boll wall during feeding afforded an entry for the boll rot fungi. Two fungi were found in this field, *Rhizopus nigricans* Ehr. and *Aspergillus niger* Tiegh. There was no significant difference between treatments with respect to the number of bolls found infected with these two fungi. Records made in the surrounding untreated check area showed approximately five times as many rotted bolls as were found on the plots treated with endrin.

In experiment 2 insecticide applications were started on August 10, when a preapplication count showed that over 50 per cent of the squares were injured.

Endrin at both 0.5 and 1 pound per acre gave significantly better bollworm control than either dieldrin at 1 pound or toxaphene at 6 pounds (Table 1). There was no significant difference in control between the two rates of application for endrin. Toxaphene gave slightly better control than dieldrin, although the difference was not significant. The higher dosage of endrin gave a significantly greater yield than any of the other treatments and the lower dosage a significantly greater yield than dieldrin. There was no significant difference in yield between toxaphene and dieldrin treatments. All treatments gave excellent increases in yield when compared with that of the untreated check.

The bollworm control and yields obtained in this experiment are outstanding, considering the fact that insecticide applications were begun late in the season and under conditions of an extremely heavy infestation.

DISCUSSION.—A build-up of spider mites, *Tetranychus* sp., developed during September in experiment 2. No population counts were made; however, observations showed that the infestation was considerably heavier in the plots treated with endrin and dieldrin than with toxaphene or on the untreated check plot. One application of dusting sulfur gave fair control.

Observations in cotton fields during December showed that many pupae of the bollworm could be found attached to the soil surface or to such surface debris as shed bolls or leaves. A count made in January in experiment 2 showed that there were significantly more pupae found on the soil surface in the plots treated with toxaphene and dieldrin than with endrin. All treated plots had considerably fewer pupae than the untreated check plots.

A Method for the Evaluation and Retreatment of Insecticide-Treated Cotton Strings Used for House Fly Control

R. C. BECHTEL and A. A. GRIGARICK, *University of California, Davis*

As a supplement to the sanitary measures of the fly control program on the Davis Campus, insecticide-treated cotton strings were used during the 1953 season. In order to obtain an indication of the effectiveness of two organic phosphates and the string method of control, a new system for collecting flies under field conditions was used. Also, a rapid method of string retreatment was devised.

Three-foot lengths of #16 cotton string previously soaked in various insecticide concentrations and sugar solutions (Table 1) were tied, one string each, to flat, circular, cardboard trays 9.5 inches in diameter and with a 0.75-inch lip by means of previously attached tray strings. The lower end of the treated strings terminated approximately 3 inches above the trays. These treated strings together with their trays were then placed at intervals of 2 feet on beams in an animal barn by means of staples. Tray collections and counts were made every 3 days for a period of 36 days. The results are given in table 1.

Table 1.—Experiment on house flies using emulsion-treated cotton strings.

MATERIAL AND PER CENT	ADDITIVE	ORIGINAL CONDITION OF STRING	NUMBER OF REPLICAS	AVERAGE NUMBER OF DEAD FLIES[1]
Malathion, 5	sugar, 10%	new	4	936[2]
Malathion, 5	sugar, 10%	fly-specked	4	1027
Malathion,[2] 5	sugar, 10%	fly-specked	2	1643
Malathion, 50	sugar, 10%	new	4	596
Diazinon, 5	none	new	4	860
Diazinon, 5	sugar, 10%	new	4	912
Diazinon, 5	sugar, 10%	fly-specked	4	1434
Diazinon, 25	none	new	4	774
Diazinon, 25	sugar, 10%	fly-specked	4	777
Check —	none	new	2	37
Check —	sugar, 10%	new	2	88

[1] The final averages were obtained by totaling the averages of each 3-day count.

[2] These were retreated strings which had been in use for 3 weeks prior to the test and were not treated again before their inclusion in the test.

[3] Although fly populations fluctuated somewhat and fell off due to weather conditions near the end of the test, there was no observed decline in killing power of any of the strings during the 36-day period.

The flies collected on each tray were not considered to be the total kill since the insecticides employed may not have caused immediate death. Also, during daylight hours there was some movement between and away from the strings or away from the trays. At night, however, the habits of the flies were such that the majority of those affected while resting upon the strings fell into the trays. The placement of the strings and trays in a semi-open area, which was subject to excessive air currents, occasionally gave incomplete results due to the swaying and tilting of the apparatus. Placing the strings and trays directly over the animal stalls in order to secure the most effective results also required elevating them to a height where they were not disturbed by the animals.

In areas where no tests were conducted, strings impregnated with 10 per cent sugar together with either 5 per cent malathion or 5 per cent Diazinon and without collection trays had already been in use for several months. Although no decrease in residual action was shown during the test period, observations during the previous months indicated that replacement at various intervals by retreated or new strings gave increased kills. Consequently, because removal, retreatment, and rehanging, or replacement with newly treated strings was too time-consuming, the following method was used. A glass tube 3 feet

in length, 1 inch in diameter and closed at one end was inserted into a protective aluminum pipe which was slightly larger in diameter, but shorter in length. The extended part of the glass tube made the level of the solution visible. It was not necessary to weight the bottom end of the strings before retreatment because they had originally been impregnated with 10 per cent sugar and therefore became stiff upon drying. The resulting lack of buoyancy of the strings made treatment with the tubes very easy. After submerging the string in the solution it was allowed to remain momentarily and then the tube was slowly withdrawn in order to permit some drainage.

Despite several disadvantages, it appears that field data may be obtained for checking the effectiveness and residual action of treated strings by use of the tray method. Also, retreatment by the tube method is economical from the standpoint of equipment, amount of insecticide, and personnel required.

An Introduced Slug, *Arion ater* (L.), and Its Control with Metaldehyde

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An introduced slug has recently become abundant in western Washington. Specimens have been determined as *Arion ater* (L.) by H. A. Rehder, of the U. S. National Museum.

This slug was first reported in the Pacific Northwest by Thompson (1942). In his reports of its occurrence in Multnomah County, Oregon, he stated that it had previously been known to occur only in one locality in the United States, a garden in Detroit, Michigan. Glendenning (1952) has reported it in British Columbia. John E. Davis (in correspondence) stated that Oregon Department of Agriculture records indicate that the slug is abundant at several coastal locations in Oregon as far south as Rockaway (Tillamook County) and in the Willamette Valley at Salem.

Current information indicates that *Arion ater* is present in the territory extending from Marion County, Oregon, northward through Washington into British Columbia, on the west side of the Cascade Mountains. Since 1948 this slug has become the dominant species affecting gardens in the lower Puget Sound area of Washington. Complaints have been frequent that the slug baits on the market were ineffective against this species.

General observations of the habits of *Arion ater* have been made at Sumner, Washington. These slugs start moving out of their daytime hiding places as dusk approaches, and feed on many types of plants during the night. This activity continues through the spring, summer, and early fall. There seems to be a single generation annually, and the winter is spent mainly in the egg stage or as very young individuals. A few of the older slugs live through the winter under special protective conditions. In the spring the slugs are small. They gradually increase in size and reach maturity in the summer. During the summer months, when narcissus bulbs were being dug at Sumner, the half-grown or larger slugs were frequently encountered hiding in crevices in the soil and sometimes close to the bulbs. A few egg masses were observed as early as mid-July, but the peak of egg laying occurs in late August and early September. The presence of very small slugs during October and later in the autumn indicates that the earlier deposited eggs hatch before winter.

During the summer of 1953 it was estimated that there were approximately 20,000 slugs in the $\frac{1}{3}$ acre devoted to the growing of narcissus bulbs in the laboratory plot at Sumner. The harvesting of these bulbs in July cleared much of the vegetation from the soil surface, and the slugs that were not killed during the digging operations moved into the grass and mixed weeds at the margins of the plot. This situation provided an opportunity to test insecticides against the slugs.

As a preliminary operation the soil adjacent to the margins was tilled lightly to retard new weed growth and then raked smooth. About 1 foot from the grassy growth 5 grams of a dust containing 15 per cent of metaldehyde was applied to the soil surface in a narrow band 10 feet long. In an adjacent strip, also about 1 foot from the plot margin, 37 grams of a pellet bait containing 2 per cent of metaldehyde in a bran base was applied in a similar 10-foot band. The dust was effective for 5 days, during which 16 slugs were killed. The bait was effective for 12 days, during which 50 slugs were killed.

In a second test a pair of similar bands were placed on slightly dampened fallow soil the day after a light rain. The same quantity of dust was used, but only half the quantity of bait. The effectiveness of the dust lasted for 7 days and of the bait 8 days. Thirteen slugs were killed by the dust and 52 by the bait. All the slugs killed were *Arion ater*, with the exception of seven large gray garden slugs killed by the bait.

The comparison of the effectiveness of the two forms of metaldehyde on fallow ground indicates a marked superiority of the bait over the dust. However, when the bait was applied in vegetable or flower gardens, it was only moderately effective. It did not seem to attract the slugs when in competition with plant foliage. In contrast, narrow bands of the 15-per cent dust were very effective when spread along the edges of flower beds or around locations in vegetable gardens where the slugs hide during the day. This effectiveness appeared to be due to placing the dust in such situations that the slugs would cross the bands during their nocturnal migrations. During the period of these tests there was very little rainfall, and the dust strips remained effective for 6 or 7 days in the absence of rain. The dust apparently lost its effectiveness after precipitation of 0.25 inch or more.

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DEDICATION OF NEW ENTOMOLOGY RESEARCH LABORATORIES AT ORLANDO, FLORIDA

On March 20, 1954 new entomology research laboratories were dedicated at Orlando, Florida by the Hon. Ezra Taft Benson, Secretary of Agriculture and Dr. H. N. Worthley, Office of the Assistant Secretary of Defense for Research and Development.

The laboratories will provide excellent facilities for continuing research on the control of insects of medical importance to military personnel. The research programs at Orlando are conducted by the Entomology Research Branch, Agricultural Research Service, U. S. Department of Agriculture with funds made available by the Department of Defense. The research at Orlando has been under way since 1942 with funds provided by the Office of Scientific Research and Development and by the Department of Defense.

Representatives of a number of federal, state and industrial institutions were present for the occasion, including the Department of Agriculture, Department of Defense, U. S. Public Health Service, Tennessee Valley Authority, Florida State Experiment Station, Florida State Board of Health, National Pest Control Association, National Agricultural Chemicals Association, Chemical Specialties Manufacturers Association, Entomological Society of America, Florida Anti-Mosquito Control Association, and others.

The dedication ceremony was also attended by a number of members of the United States Congress, the Florida State Legislature, Florida State Cabinet, and Florida State Agricultural Associations. These distinguished visitors were introduced by Mr. J. A. Mulrennen, Florida State Board of Health.

Secretary Benson and Dr. Worthley in their dedication addresses praised the contributions of the Orlando laboratory in protecting military and civilian personnel from attack by insects and from diseases transmitted by insects. The statements by these distinguished representatives of the U. S. Department of Agriculture and the U. S. Department of Defense, respectively, indicate the growing recognition of the significant role that entomology plays in our nation's welfare.

We are happy to have the privilege of submitting for publication the addresses by Secretary Benson and Dr. Worthley in dedicating the new laboratory at Orlando.—E. F. K.

DEDICATION STATEMENT FROM THE DEPARTMENT OF DEFENSE[1]

First, I bring you greetings from the Secretary of Defense, Mr. Charles E. Wilson, and from the Assistant Secretary for Research and Development, Mr. Donald A. Quarles. They regret their inability to join Secretary Benson on this pleasant occasion. It is a great pleasure for me to represent them, however, not only to join in this ceremony but also to renew old associations and to come to the pleasant city of Orlando to do so.

For the people of Orlando, during the dark years of World War II, when our country was straining its every sinew to produce the means to destroy our enemies, it must have been a source of quiet satisfaction to realize that among them were working, at top speed and with all their skill, a small band of researchers whose mission was not to destroy life but to preserve it.

The program at the Orlando Laboratory has always been strongly endorsed in the Department of Defense. It is a fine example of the continuing effort of the Department to have its needs supplied by those who can best fill them, rather than to create its own competing organizations. To this end the Department attempts to enlist the help of other governmental agencies, of the universities, of industry, wherever the necessary competence exists.

[1] Remarks by Dr. Harlan N. Worthley, Office of the Assistant Secretary of Defense (Research and Development) at dedication of Entomology Research Laboratory of the United States Department of Agriculture at Orlando, Florida, 20 March 1954.

In this case, the needs of the Armed Services for means to control insects of medical importance, to protect military supplies and equipment from insect damage, and to develop the necessary chemical standards, testing services, formulations, and military specifications were entrusted to the Department of Agriculture to supply. Its entomologists possessed the administrative ability and technical background to plan, initiate, direct, and conduct research and development in this area most expeditiously and economically. The Department of Agriculture was willing to accept this additional burden, and others as well.

How splendidly this program has paid off during the war and since, remains for others to tell. It suffices for me to say that through prompt application of the results of this program thousands of soldiers, sailors, airmen, and marines are alive and well today who might otherwise be dead or crippled, and millions of dollars worth of military stores and structures have been saved from destruction.

The new facilities that we are dedicating today express the intention to continue this program. The experience in Korea explains why this is necessary. When it was discovered that the lice encountered there were resistant to DDT, we faced the imminent threat of an outbreak of louse-borne typhus that would have decimated the military forces and civilian populations alike. Had the small laboratory program at Orlando been abandoned it would certainly have taken a year or more to organize an investigation and find a solution to the problem. In fact, a solution was found here within three months, and the threat of a serious disease situation disappeared.

Several agencies of the Armed Forces have presented their problems to the Orlando laboratory and have assisted in its program. The Army Surgeon General, the Quartermaster General, the Chief of Engineers, the Chief Chemical Officer, working through the Army Committee on Insect and Rodent Control, and their counterparts in the Navy and Air Force, have reaped the benefits of this program. And health agencies from all over the free world now look to this laboratory for leadership and help in the problems of insect-borne disease.

The annual savings to the Armed Services from the work of the Orlando program exceed its cost many times over. No dollar value can be placed upon its contributions to the health of our servicemen and of people everywhere. Those responsible are very modest about it all. True researchers, they ask little beyond a decent recognition and application of their findings and the means to do a better job. Mr. Secretary, the Department of Defense is pleased to join you in giving the staff of the Orlando laboratory the improved opportunity represented by the new laboratory that we are dedicating here today.

THE VALUE OF RESEARCH[1]

It is a privilege and an honor to be here with you on this memorable and historic occasion. This is a glorious day.

I always appreciate the opportunity to come to Florida—especially in the winter, while much of this nation still has winter weather.

I love Orlando. Your city, with its gardens and trees, its lakes and parkways, is delightful.

I want to express my deep appreciation for all the kindnesses I have received from this very hospitable community and from your distinguished state officials. But most of all, I am glad to be here because of what this great Entomology Research Laboratory here in Orlando represents.

Too often when we talk about the value of agricultural research we think only in terms of material benefits. But when we consider the research here at this Laboratory, we realize that it far transcends material considerations. We cannot begin to estimate the value of the work done here with DDT and other new insecticides. It It has saved countless people from death due to insect-borne diseases. It has raised health standards throughout the world.

Twelve years ago—in 1942—in response to the urgent request of military advisors on health problems, the Department of

[1] Remarks by Secretary of Agriculture Ezra Taft Benson at dedication of Entomology Research Laboratory, Orlando, Florida, March 20, 1954.

Agriculture assigned some of its most experienced and capable entomologists and other specialists to concentrate on research to protect our military personnel against insect diseases. Funds were provided by the Office of Scientific Research and Development of the National Emergency Council.

The scientists here at Orlando were confronted by a tremendous job. Our armed forces were scattered around the globe—in places where many kinds of disease-carrying insects were rampant. They had to act fast. There was no time for long drawn-out, methodical research. They had to cut corners wherever possible. They had to keep in close touch with industry, which assumed the responsibility of manufacturing or formulating the products. They had to consult with toxicologists, who had the responsibility of judging if the materials were safe to use on man.

We know what happened. Insecticides were developed that no doubt saved thousands of lives and prevented the loss, through disease, of hundreds of thousands of man-days. Science gave us effective weapons against lice, mosquitoes, and flies. These insects can cause as much damage as the human enemy in time of war. In 1945 the Army and Navy actually treated entire islands in the Pacific and extensive areas in other war theaters to control mosquitoes and flies. In 1944 a typhus epidemic was raging in Naples, Italy. It was stopped in its tracks by the use of DDT.

There are always many unsung heroes in war. There are always a few to whom the many owe more than they ever know. So it was here at Orlando. Between 1942 and 1945, the number of persons involved in this insect research work here averaged less than the number of one company of infantry. The money spent was less than the cost of one of the smallest cargo vessels. Yet the findings of this group of researchers now form the basis for our present methods of controlling some of the most devastating and debilitating diseases of mankind. My humble tribute to these our benefactors.

Today, a widespread epidemic of malaria can be stopped within hours by the comparatively simple expedient of applying 2 quarts of a 5 per cent DDT solution per acre from an airplane. Flies, which carry dysenteries, typhoid, cholera, and other diseases can be brought under control.

Although these insecticides were designed for military needs, they can be revised, modified, and used for the benefit of a world at peace. Entomologists and others from around the world have come here to learn at the Orlando Laboratory. They returned to their homelands bearing information that is being applied to their peculiar insect problems. In 1947 the U. S. Department of Agriculture paid its official respects by giving its award for Distinguished Service to this Laboratory.

The end of World War II, of course, did not bring an end to the need for research on military problems of insect control. American occupation forces remained in many areas. Insecticides and repellents were still needed to protect our military personnel. We had to develop insecticides that did not depend on imported materials, such as pyrethrum. We had to accumulate reserve stocks of insecticides. Then, too, you remember that certain insects began to develop resistance to DDT—so alternate insecticides were needed.

To help provide answers to these and many other problems of military importance, the Department of the Army has each year transferred funds to the Department of Agriculture to continue these specialized studies. The Department of Agriculture, in turn, has made available its vast background of information on insecticides and insect behavior.

Although the studies have a military objective, their actual value has been much more far-reaching. A very large part of the information developed has been adaptable to civilian uses, both here and abroad. The World Health Organization, for example, has recently undertaken a global survey of insecticide resistance in lice—one of the most dreaded carriers of diseases. The survey is based on methods developed here during the evaluation of new powders for the control of resistant lice.

So the advantages are mutual. Much of the progress here of military importance has been made possible because of knowledge and experience gained in the Department's regular entomological research programs. But the Department has also benefitted indirectly from the new insecticides and other materials developed here.

Allethrin, a substitute for pyrethrum, was developed in the Washington laboratories for agricultural purposes. Further development for military use was done here. On the other hand, information on a number of insecticides investigated here at Orlando has been of great importance in their further investigation for use in agriculture.

As Secretary of Agriculture, I want to express appreciation of the confidence placed in our scientists by the medical and other specialists in the armed services and by the Office of Scientific Research and Development. These agencies requested the Department to undertake the research programs during the war, and they furnished the necessary funds. And we appreciate, too, the opportunity to continue the research since the war with funds provided by the Department of Defense.

To provide more adequate facilities to the research personnel doing this vital work, we have joined with the Department of Defense in financing the construction of these new laboratory facilities. The Department of the Air Force made this ground and these buildings available. Funds for their renovation were provided jointly by the Department of Defense and the Department of Agriculture. With the improved facilities and a continuing zeal, we can look forward with confidence to additional progress in the solution of these specifically military problems, with incidental but important benefit to agriculture and the entire American people.

May a kind Providence bless and guide this vital work.

It is with great pleasure that I dedicate this Entomology Research Laboratory, with its facilities for developing new and improved methods of controlling harmful insects, to the service of the armed forces, the agriculture of our Nation, and the welfare of all the people of the United States.

Egg-Laying Periods of the Red-Banded Leaf Roller in Southern Pennsylvania[1]

DEAN ASQUITH,[2] *The Pennsylvania State University*

In Southern Pennsylvania, one of the difficulties in controlling the red-banded leaf roller, *Argyrotaenia velutinana* (W kr.), is timing spray applications to kill the maximum number of larvae of each brood. The key to this problem is the length of time eggs for each of the three broods are deposited by parent female moths of the preceding generation.

During 1952 and 1953 on the laboratory farm in Arendtsville, the seasonal development of the red-banded leaf roller in cages and on young apple trees in the open was observed closely to determine the first and last dates eggs for each brood were deposited. For each generation, the last 7 to 10 days of egg laying were observed in the field after egg laying in the cages had ceased. The records for both years are shown in table 1.

Table 1.—Egg-laying periods of the red-banded leaf roller in Southern Pennsylvania.

Brood	Year	Date Eggs Deposited		Number of Days Eggs Deposited
		First	Last	
First	1952	April 16	May 14	29
	1953	April 1	May 10	40
Second	1952	June 16	July 14	29
	1953	June 10	July 10	31
Third	1952	July 25	August 23	30
	1953	July 21	August 24	35

Frost (1925), who also worked in Arendtsville, reported much shorter egg-laying periods for all three broods than those listed in table 1, but his study of this factor was limited to caged specimens. The average egg-laying period of 32.3 days reported in this paper is approximately twice as long as the average of 16.3 days based on Frost's figures. A review of the weather records for this area shows that the weather during the period of Frost's study was similar to the weather in 1952 and 1953 and, therefore, cannot reasonably be considered an explanation for the difference. There is, of course, the possibility that the present strain of red-banded leaf roller infesting Southern Pennsylvania orchards is different from the strain that was here 30 years ago. Hough (1927), whose studies of the red-banded leaf roller were made in Winchester, Va., reported egg-laying periods ranging from 28 to 60 days, with an average of 41 days or an 8.5 day longer average period than the one reported herein for Southern Pennsylvania.

During the last few years, both entomologists and fruit growers in Southern Pennsylvania have attempted to control the second and third broods of the red-banded leaf roller by applying one spray of a suitable toxicant against each of these broods. The data in table 1 indicate there is reason to expect this type of control program to fail expecially during seasons in which conditions are favorable for the development of this pest. In the fall of 1953, fruit in some orchards that harbored heavy infestations of the red-banded leaf roller, was injured because the residue from one spray of TDE applied in early August did not remain toxic long enough to kill the larvae that hatched from eggs deposited after August 15.

Literature Cited

Frost, S. W. 1925. The red-banded leaf roller. Penn. State College School of Agr. and Expt. Sta. Bul. **197.**

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BOOK REVIEWS

THE COMSTOCKS OF CORNELL. By Anna Botsford Comstock, edited by Professors Glenn W. Herrick and Ruby Green Smith. Comstock Publishing Company, Ithaca, N. Y., 1953; xiii+286 pages. Price $4.50.

This charming autobiography describes the lives of two of the most beloved and honored of all Cornellians. John Henry Comstock entered Cornell in 1869, one year after the founding of this institution, and Anna Botsford came five years later. They were married in 1878 and for half a century they lived and labored together there, except for a two-year period, 1879–81, spent at Washington where Professor Comstock served as Chief Entomologist in the U. S. Department of Agriculture. The book is more than a record of the very full and interesting lives of these two extraordinary scientists and teachers. It is also a story of the development of a great institution of learning.

Professor Comstock created here the renowned Department of Entomollogy that was to produce numerous outstanding workers in this field. Always insisting that it is as important to know what insects do as it is to know their names, he significantly extended the Department's facilities in 1887 by constructing an insectary. It was the first building of its kind and has served a long line of investigators, both graduate students and staff members. Mrs. Comstock, while participating continually in her husband's undertakings, herself became Cornell's first woman professor and created the first Department of Nature Study to be developed at any American university.

Probably very few even of those who knew the Comstocks well were familiar with Professor Comstock's lonely and troubled boyhood and youth that are pictured in touching detail by Mrs. Comstock. Her own more sheltered early life is described much more briefly but there is sufficient detail here also, to provide a nice setting for the later story. Few, too, have known of the Comstock's successful venture as part-time farmers which was carried on with the same determination and thoroughness as their scientific investigations.

The Comstock home at Cornell was always a hospitable place. As Mrs. Comstock puts it, "During our first year together Harry and I began an enterprise which we carried out as consistently as possible for forty years, the entertaining of Professor Comstock's students in our home." Numerous allusions are made to gatherings there of students and others, and the reader is given a nice picture of delightful home life. Here and there throughout the book one also meets, and even comes to know, many of the outstanding entomologists of the period, including among others C. V. Riley, L. O. Howard, Vernon Kellogg, Samuel H. Scudder, H. A. Hagen, Theodore Pergande, C. H. Fernald, George Marx, Mark Slingerland and Alex. MacGillivray.

A commendation from Signoret, French authority on Coccidae, of Mrs. Comstock's drawing of a male coccid started her on a career as an artist in natural history. She also took up wood engraving in the early eighties in order to illustrate her husband's books and she became extraordinarily proficient in it. This proved to be of the greatest importance for above all else the Comstocks were writers. Naturally the preparation of their many books is discussed, and there are intimate details of the trials, hopes, disappointments, pleasures, anxieties and satisfactions encountered with each.

C. F. W. MUESEBECK

THE COCONUT RHINOCEROS BEETLE (*Oryctes rhinoceros*) WITH PARTICULAR REFERENCE TO THE PALAU ISLANDS, by J. Linsley Gressitt. 1953. Bernice P. Bishop Museum Bulletin No. 212. 157 pp. with 50 illustrations and 16 tables.

The coconut rhinoceros beetle was introduced into the central Palaus by Japanese shipping at an early stage of World War II. In this area, released from the natural controls of its native home and offered abundant food, it increased in numbers and spread rapidly. The problem was aggravated by damage to coconuts by gun fire during the war. The beetle now threatens the entire economy of the Trust Territory.

In this article, published in November of 1953, Dr. Gressitt has presented a very interesting and detailed ecological life history of this important insect pest. After an introduction, which gives background information on the Palau Islands and the host plant, he takes up taxonomy, morphology and biology, ecological relationships in the Palau Islands, and control. These major sections are followed by comments on the importance of quarantine and the beetle in other areas. A bibliography of 310 references and an index complete the paper.

Due to the widespread and diverse breeding habits of the larvae and the inaccessibleness of all stages, chemical control is not feasible economically or otherwise. Much effort has been spent on biological control, but has not been successful to date. The correlation between the abundance of available larval breeding sites and damage by the adults has suggested the utilization of sanitation programs. This procedure, coupled with trapping, has been the most successful to date. The ecological basis of this control is not clear from the text.

Although the author has given a thorough factual summary of his information and that of the literature, much remains to be done in the way of a critical analysis of the population dynamics of this species. Nevertheless, this important paper will stand as a manual for anyone interested in life history, habits, and control of the coconut rhinoceros beetle.

RAY F. SMITH,
University of California, Berkeley

FUNDAMENTALS OF ECOLOGY, by Eugene P. Odum, W. B. Saunders Company, West Washington Square, Philadelphia, Pennsylvania, 1953. 5½×8½ inches. 384 pp., 119 figures. $6.50.

Recent years have witnessed increased appreciation of the important role of ecology in both the fundamental and applied phases of biological study. For several years there has been a well-recognized need for a textbook setting forth the principles of ecology in a concise, simplified and readily understood manner sutiable for the needs of an introductory college level course. In writing this text Dr. Odum has been guided by 15 years of teaching experience at the University of Georgia. The subject matter has been arranged in the manner which he has found to be most effective. Of the 14 chapters comprising the book, the first eight concern basic

principles. These are grouped under such subjects as "Ecosystem and Biogeochemical Cycles," "Limiting Factors," "Energy and Ecological Systems," "Organization at the Community Level," etc. Throughout these eight chapters the principles are set forth as statements, each followed by one or more pargraphs of explanation which are in turn followed by an example illustrating the function of the principle or concept involved.

The absence of a mass of complicating detail may tempt the student to think of ecology as a less complex subject than it actually is. Such a misconception, if it arises, may be readily corrected by pointing to the interdependent and interlocking nature of all ecological concepts. Nevertheless it is no easy task to acquaint the student with the forest without losing him in the trees.

In Part II the student is introduced to at least a portion of the trees. This part is termed "The Habitat Approach" and is subdivided into three chapters, dealing respectively with freshwater, marine, and terrestrial ecology. Here the "principles" are reexamined as they are found to apply to the animal inhabitants of the earth's surface. Emphasis is placed on ecosystems, which are defined as the functional units of ecology, each consisting of living and non-living parts interacting to produce a stable system.

The chapters on organization at the species population level, the interspecies population level, and the community level reflect the importance of the biometrical approach to these problems. Natural ecological classification is treated under "Terrestrial Ecology" and the term "Biome" is used to designate the largest land community unit which it is convenient to recognize. These are areas over which the life form of the climatic climax vegetation is uniform.

The book concludes with Part III, which concerns the applications of ecology which contribute to the well being of human society. Three short chapters treat applications to "Natural Resources," "Public Health and Welfare" and "Human Society." The first two refer to research of the kind intended either to bring about the maintenance or increase of desirable organisms or to diminish the numbers of undesirable species. The last chapter presents a brief but interesting summary of human ecology in which man's culture and economy are examined in the light of ecological principles.

A well rounded course in ecology requires some field and laboratory work if the student is to gain any first hand experience in the methods, instrumentation, and technical difficulties encountered in ecological research. Odum refers to these only indirectly as he cites examples to illustrate principles. Otherwise his "Fundamentals of Ecology" appears admirably suited "to serve as a textbook in a college course and also as a reference for the naturalist—conservation workers, sanitary engineers and other applied ecologists who need to be familiar with the background work and theories in ecology."

R. I. SAILER

AN ENTOMOLOGIST'S QUEST, Charles Lester Marlatt, 1953. Monumental Printing Co., Baltimore, Md.

In this volume of 338 pages, Dr. Marlatt presents the entomological results of his successful efforts to locate the original home of the San Jose scale and to collect and transport to the United States parasites and predators of the scale, "this worst of all deciduous fruit pests."

It may be difficult for present day entomologists to visualize the importance of this endeavor, the difficulties encountered and the pioneer nature of the survey, but reference to the recent literature on the Oriental fruit fly in Hawaii should convince them of the very great threat of the introduced San Jose scale to American agriculture. In that day entomology lacked the present day multiplicity of potent insecticides with which an invader now may be eliminated or retarded.

The diary that might easily have been tedious and dreary is enlivened by anecdotes, side lights on the character of some of the guides, officials and travelers encountered and comments on customs and shopping expeditions.

ERNEST N. CORY

NEOTROPICAL CULICIDAE. J. Lane. 2 vols., 1112 pp. illus. University of São Paulo, Brazil. 1953 (Obtainable in this country from John D. Sherman, Jr. Mount Vernon, N. Y. $15.00).

This large work by one of the world's leading culicidologists will be indispensable for anyone attempting to determine mosquitoes from South America, Central America, or the West Indies. It is the only work since Dyar's *Mosquitoes of the Americas* that attempts to cover the rich fauna of this large area. The author had the opportunity to study original material in the British Museum and at the U. S. National Museum, and in addition has had long experience with the mosquitoes of South America, particularly Brazil.

The author includes three subfamilies, the Dixinae, Chaoborinae, and Culicinae, only the latter containing bloodsucking species. In all, approximately 640 species are keyed and described, and there are 1071 figures scattered through the text. Larvae and pupae are described as far as these are known. The first volume contains an introductory portion of 29 pages with a brief discussion of mosquito anatomy, an historical summary, and a general bibliography. The rest of this volume is taxonomic and covers the Dixinae (genus *Dixa*), Chaoborinae (5 genera) and the tribes Toxorhynchitini, Anophelini, and the genus *Culex* of the tribe Culicini. The second volume contains the 8 other genera of the Culicini, the 5 genera of the Sabethini, and an index for both volumes. There are 12 separate bibliographies for various portions of the family, and each species has the references to it for taxonomic status and synonymy prior to 1939 and all other references since then, thus supplementing Lane's catalogue. It is not evident from the title pages or the introduction that N. L. Cerqueira collaborated on the genera *Aedes*, *Psorophora*, and *Haemagogus*, but a separate title page (p. 631) gives this information.

It is not to be expected that this work is free of errors, and future workers will undoubtedly point them out. In a work of this magnitude, covering many species that were inadequately described or based upon poor or scanty material, it is impossible to determine with certainty all of them. It is quite possible that as our knowledge of the species grows some of the species that here stand in synonymy will be found valid. The work does, however, provide an excellent base for future work on the family, and will remain, for many years as the essential work on the subject. One only wishes that time and space had permitted taxonomic notes on the species that would explain the basis on which the synonymies were made. The English speaking part of the world is favored by the language in which this work is published.

ALAN STONE